

**364**  
AMAZING IMAGES  
& CUTAWAYS INSIDE

THE MAGAZINE THAT FEEDS MINDS

# HOW IT WORKS

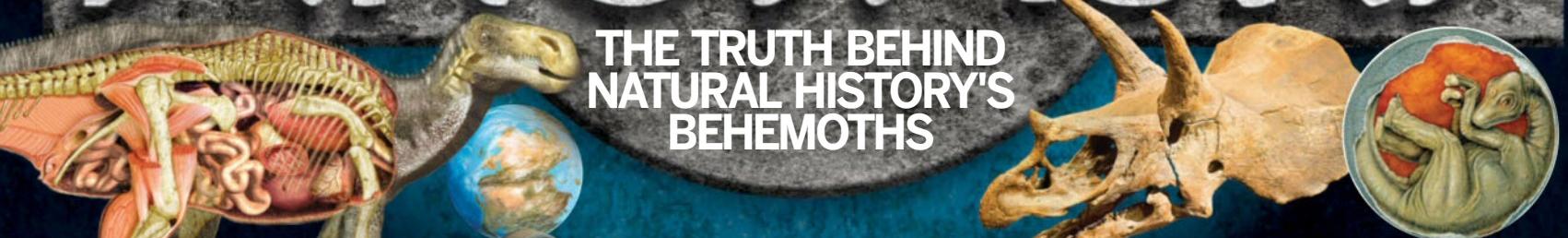
INSIDE

## 101 GIGANTIC FACTS ABOUT DINOSAURS

THE TRUTH BEHIND NATURAL HISTORY'S BEHEMOTHS

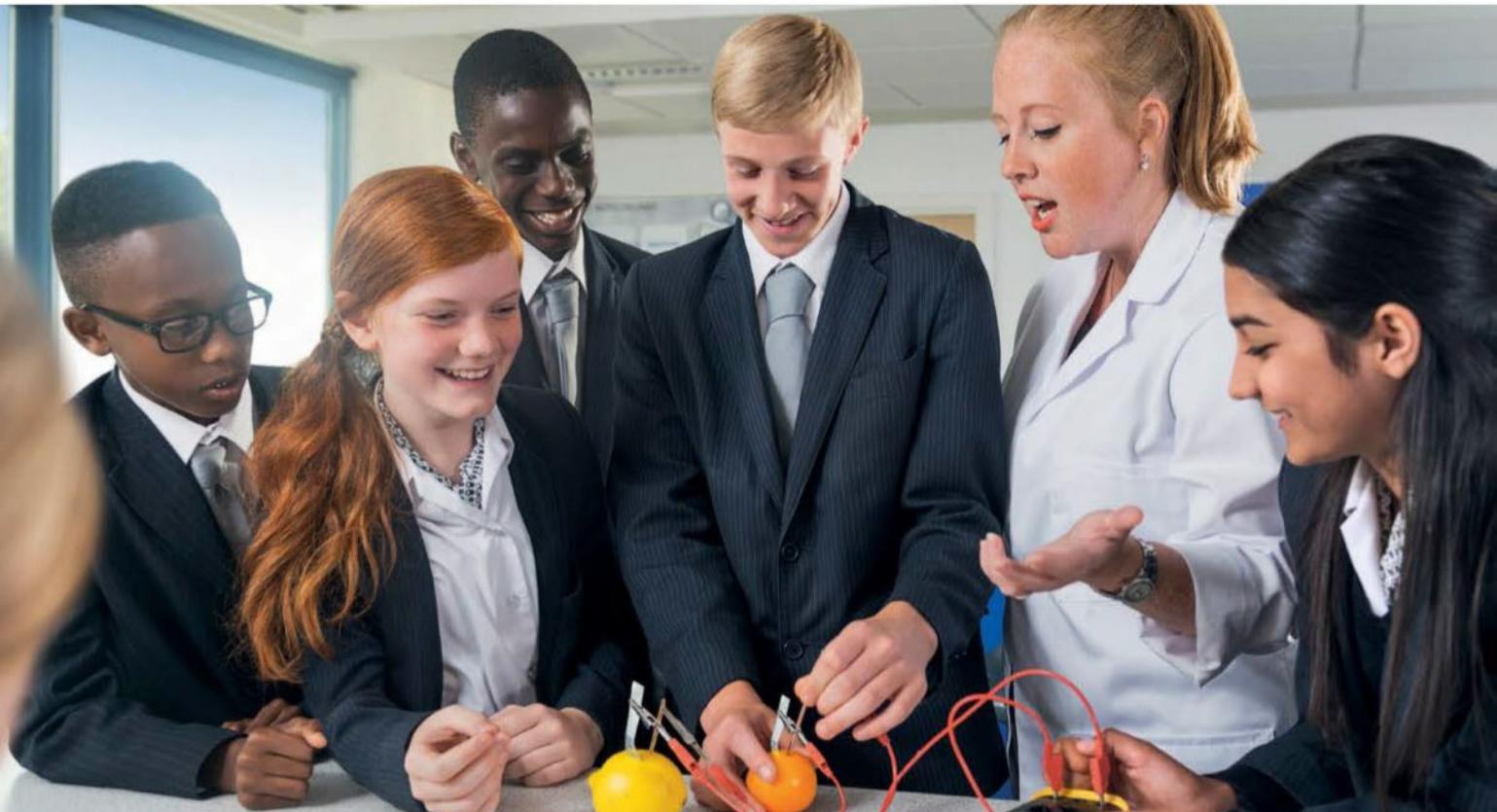
FACT!  
**T-REX**

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THAN IT DID TO THE  
STEGOSAURUS!



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# WELCOME

The magazine that feeds minds!

Page 62  
What is it like to work on a farm?



Lawyers – grab the Imodium – *Jurassic World* is almost here. The revived childhood classic is stomping back into cinemas, two decades later. It's astounding how much things have changed. We now know that most of those scaly reptiles were covered in feathers, and it was only recently revealed that while reviving a woolly mammoth might be possible, a T-rex's DNA would have decayed by now.

That won't stop the scientists in the film, though. The genetic engineers have created the most fearsome fictional foe yet: the Indominus rex. Once she escapes from her enclosure, she claws out her tracking implant and goes on a rampage. "Clever girl" as Robert Muldoon would say (or my

dad; he's been quoting that since 1993).

But the truth is that most dinosaurs were plant-eaters and used their knife-like claws for digging rather than ripping flesh. That's just one of the 101 facts in our special dino celebration. Just imagine how much more information scientists will have dug up in 20 more years' time! Find out in **How It Works** issue 300....



**Jodie Tyley**  
Editor

## Meet the team...



**Andy**  
Art Editor

Working on the dinosaur feature I found out there was one called the Saltasaurus. My surname's Salter, so this might be my new fave dino.



**Erlingur**  
Production Editor

After months of pitching a tractor feature, I finally got one on the cover! A fitting swansong for my final issue. Kveðja!



**Phil**  
Staff Writer

The latest forensic technology won't solve crimes as fast as we see on *CSI*, but it will speed up the process.



**Jackie**  
Research Editor

This month in the HIW office, we've practised our vocal harmonies after reading the science of singing feature. *Toto's Africa* is a team favourite.



**Jo**  
Assistant Designer

After a disappointing eclipse here in March, Svalbard has trumped us yet again, this time with the Doomsday Seed Vault.



**Jo**  
Features Editor

This month, I found out the truth about sugar while scoffing several delicious cakes made by our resident Star Baker, Jackie.

## What's in store

Check out just a small selection of the questions answered in this issue of **How It Works**...



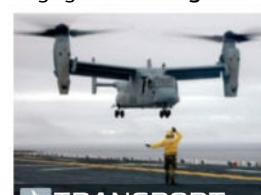
### SCIENCE

Why are people better at singing than me? **Page 46**



### ENVIRONMENT

How far do monarch butterflies travel? **Page 68**



### TRANSPORT

What is the future of VTOL? **Page 52**



### TECHNOLOGY

What are buoys actually for? **Page 32**



### SPACE

What is the story behind Hubble? **Page 76**



### HISTORY

What were armoured trains? **Page 24**

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**Twitter**  
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# CONTENTS

## HISTORY

### 12 101 gigantic facts about dinosaurs

- Some had feathers
- There were over 700 species
- None of them could fly

### 24 Armoured trains

## TECHNOLOGY

### 26 Forensic science

- Virtual reality crime scenes
- Sniff out hidden graves
- Blood pattern analysis

### 32 What are buoys for?

### 32 Cremation diamonds

### 34 Inside the Doomsday Seed Vault

## SCIENCE

### 36 The truth about sugar

- Where it comes from
- How it's processed
- Where it's hiding

### 44 Bunsen burners

### 44 The physics of foam

### 46 The science of singing

### 48 Wrinkles explained

### 50 How to check your heart rate

### 50 Household bleach

### 51 Underwater vision

### 58 Porsche 919 Hybrid

## TRANSPORT

### 52 VTOL drones

Faster, electric-powered aircraft take to the skies

### 56 Twin-clutch gearboxes

### 58 Porsche 919 Hybrid

### 60 How seat belts keep you safe

### 60 The art of emergency vehicle lighting

## ENVIRONMENT

### 62 On the farm

- Life of a dairy cow
- A farmer's daily routine
- The milking process explained

### 67 How a bottle is recycled

### 68 Life of a monarch butterfly

### 70 The fearless honey badger

### 71 Asperatus clouds

### 71 Frost flowers

## SPACE

### 72 Zombie stars

Plus six other strange celestial wonders explained

### 76 Celebrating Hubble's 25th anniversary

### 78 NASA's twins study explained

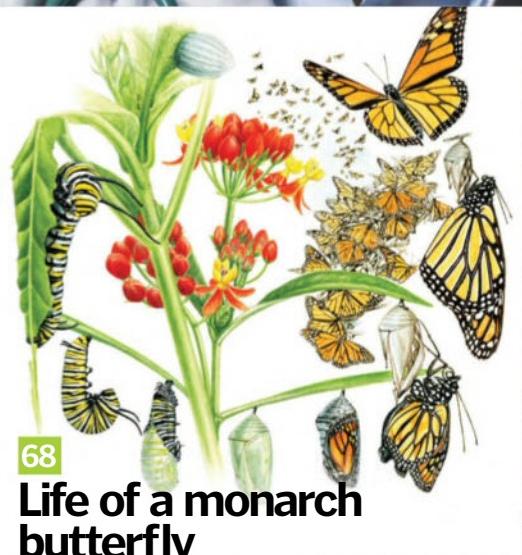
### 79 Antstronauts

### 79 How robots keep astronauts company

## 26 Forensic science



### 76 Celebrating Hubble's 25th anniversary



### 68 Life of a monarch butterfly



### 36 The truth about sugar

## Meet the experts...



### Laura Mears

101 dino facts  
You have Laura to thank for the enormous dino feature, packed with loads of great trivia. But the fact that it's impossible to tip toe around without activating your T-rex arms didn't make the cut.



### Hayley Paterek

Underwater vision  
In between prepping for her wedding, Hayley managed to explain all about wrinkles, seeing underwater and more. We wish her all the best for the Big Day!



### James Hoare

Armoured trains  
The Editor-In-Chief of All About History and History Of War takes us aboard an armoured train and explains what they're used for. They blow Wi-Fi and folding tables out the water.



### Lee Sibley

Twin gear boxes  
The Editor of our sister magazine Total 911 talks us through a variety of car tech, from gear boxes to seat belts. He has our vote to be the next Top Gear presenter!



### Tim Williamson

VTOL drones  
After writing our cover feature on Fighter Planes last month, History Of War mag's Tim looks to the future of flight. This time without Top Gun puns.

# REGULARS

12

## 101 GIGANTIC FACTS ABOUT

# DINOSAURS

72 Zombie stars

51 Underwater vision

62 On the farm



### 06 Global eye

Amazing science and tech stories from around the world

### 80 Brain Dump

The place where we answer your most curious questions

### 86 Reviews

This month, we've been testing out hi-tech camping gear

### 88 Group test

Check out the latest portable Bluetooth speakers

### 92 How to...

Make pH paper and learn how to skim a stone

### 94 Letters

Our readers have their say on all things science and tech

### 98 Next issue

Your first look at the next issue of **How It Works**



52  
VTOL  
drones

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# Army ants

The army of robots inspired by nature's hardest workers



You might think humans would be the natural inspiration for an army of robots, but German engineering company Festo has a much smaller role model. Its BionicANTs not only look like their insect counterparts, but also behave like them, as they mimic ants' ability to communicate and coordinate with each other to complete complex tasks. A group of BionicANTs, which are about the

size of a human hand, can make autonomous decisions and work together to move an object much larger than they are. Festo hopes that this approach could help improve the factories of tomorrow with a network of machines that can adjust and coordinate themselves for different production scenarios. It's not just ants that the company is interested in, though, as it has also developed a fleet of eMotionButterflies too. •

BionicANTs are made of polyamide powder, which is melted layer by layer with a laser



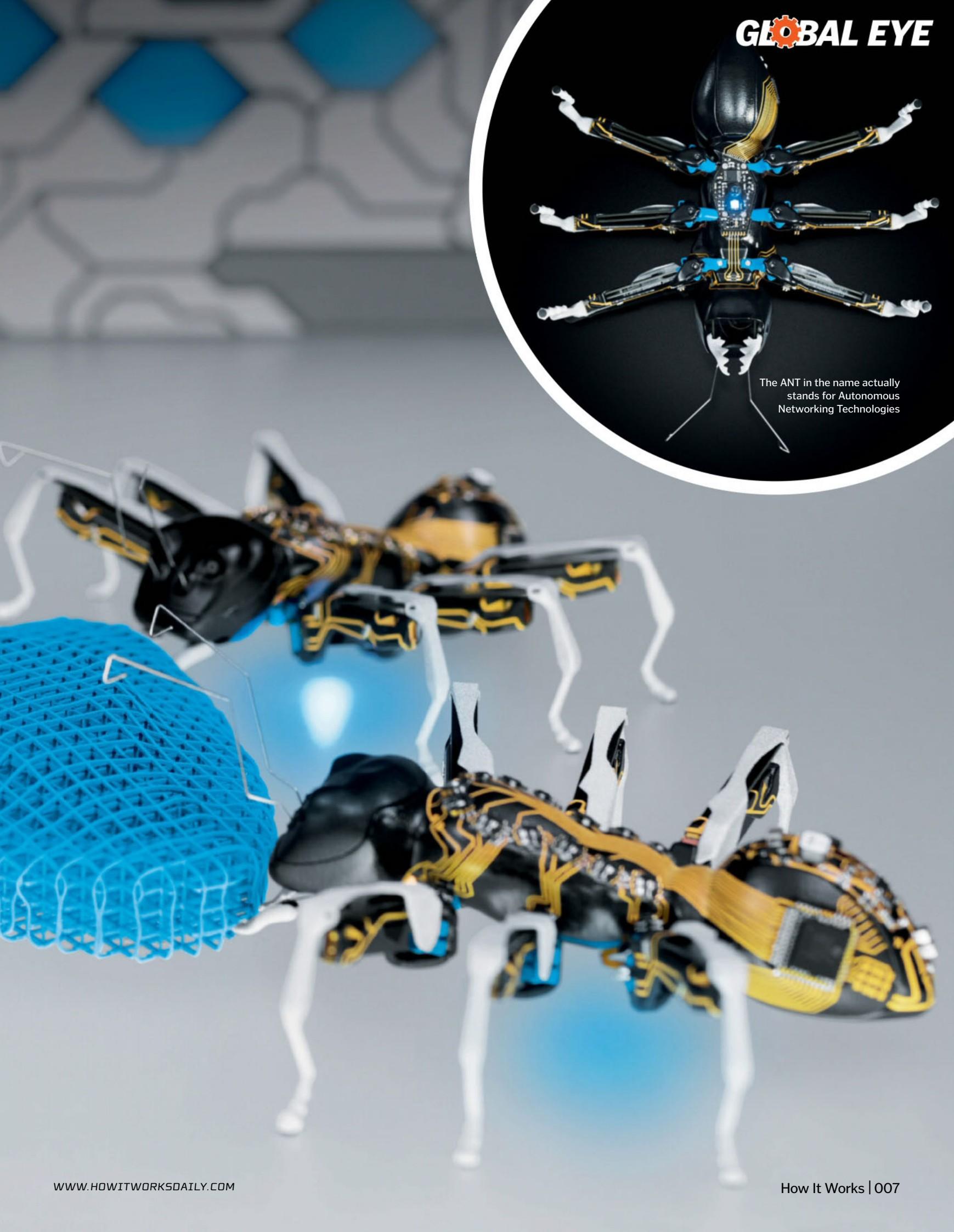
## Energy-efficient insects

Each BionicANT weighs just 105 grams (3.7 ounces) and has a 3D-printed plastic body. Its six ceramic legs and jaw, which it uses to grip onto objects, are powered by piezo technology. When the ant lifts a leg, pressure is applied to the bending transducer in its thigh. This forces the charge of its atoms out of balance, so when the pressure is relieved, an electric charge flows between them. This electricity powers the motors that keep

the robot moving, meaning it requires very little energy and therefore has a relatively impressive 40-minute battery life. However, when it does need to recharge, the robot simply has to connect its antenna to a charging station. The BionicANTs also have a camera and sensors, which they use to determine their position and navigate their environment, and can communicate with each other via radio signal.



Each BionicANT is powered by two rechargeable batteries



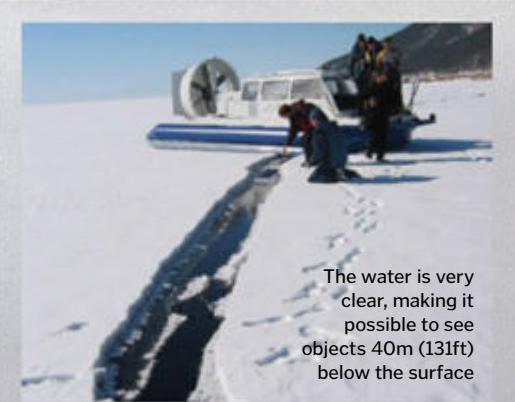
The ANT in the name actually stands for Autonomous Networking Technologies

# A cracking lake

What's splitting the world's largest freshwater lake?

 It might look like the aftermath of an earthquake, but these giant cracks actually form in the frozen waters of Lake Baikal in Russia every winter. The lake freezes over from January to May, forming a layer of crystal-clear ice on the surface that can be up to 150 centimetres (59 inches) thick in places – enough to drive a truck over it. However, the enormous cracks in the ice, which can be up to four metres (13.1 feet) wide, make it a treacherous journey, so local motorists typically carry large planks of wood with them to bridge the gaps for safe passage. ☀

Lake Baikal is the world's oldest and deepest freshwater lake



The water is very clear, making it possible to see objects 40m (131ft) below the surface

## Why does the ice crack?

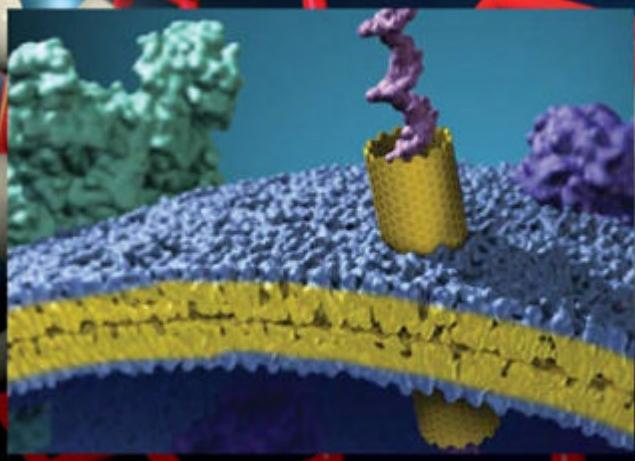
Most substances shrink when they freeze, because their molecules have less energy and so stop moving around as much. Water is an exception to the rule because when it freezes, it actually expands. This is because the positive hydrogen atoms and negative oxygen atoms of the water molecules join together to form an open crystal structure containing large holes, which takes up more space. Then, when the ice melts, the water molecules rearrange their structure to close these gaps and move closer together again, taking up less space. At Lake Baikal, the water freezes at night as temperatures plummet to below freezing, but then that ice melts a little during the day under the heat of the Sun. This constant cycle of freezing and thawing causes the ice to expand and contract every 24 hours, resulting in the formation of large cracks as the water constantly changes its density.

# Carbon nanotubes tunnel into cells

Microscopic invention could unlock precision treatments

 Scientists have created tiny tubes that can be inserted into cell membranes to transport individual molecules, and even DNA, into the living cell. These carbon nanotubes, which are 100,000 times thinner than a human hair, consist of a rolled-up sheet of

graphene and can mimic the behaviour of their natural counterparts. It is hoped they will eventually be used to deliver drugs to specific areas of the body, acting as gates that select what is and isn't allowed into each cell, and even be used to develop complete synthetic cells.



## Salty secrets of Mars

The Red Planet could be home to saltwater rivers

 After analysing the soil, temperature and humidity for a full Martian year, NASA's Curiosity rover has unlocked a new discovery. Conditions on some nights at the rover's near-equatorial location were found to be favourable for salts in the soil to absorb water vapour from the atmosphere and dissolve to form salty liquid brine. Although no such saltwater has been detected, there is a strong possibility it could exist at higher latitudes and thus explain the dark flows that appear on the slopes of Mars during warmer seasons.



Curiosity's temperature and humidity sensors helped make the discovery

# GLOBAL EYE

# 10 COOL THINGS WE LEARNED THIS MONTH



## Plants can grow without sunlight

British scientists believe they have taken a step toward solving the problem of world famine. Greenhouses fitted with LED lights have been able to grow plants without natural daylight, which could allow huge quantities of plants to be grown in disused buildings and large warehouses across the globe. Urban areas would be able to grow fruit and vegetables all year round, no longer relying on imports from elsewhere.



## Glass shape affects wine's taste

For many years, wine connoisseurs have claimed the glass you drink from affects its taste, which has been met with some scepticism. There is now scientific evidence that this is in fact true. Different glasses allow differing amounts of ethanol to escape, which affects taste. A traditional wine glass was found to have the best shape for improving aroma, while tumblers and cocktail glasses were found to suffer from interference by gaseous ethanol.

## Our brains keep us eating

We've all struggled to show restraint when presented with a box of chocolates. Scientists have now found the brain area that tells us to keep eating, and hope to be able to soon install an 'off' switch. Within a cluster of 10,000 brain cells (known as POMC neurons) are tiny triggers, which tell us to keep eating if they aren't functioning properly.



## There's a watch to check you're alive

The Assure watch continuously checks if you're alive and can inform relatives if you have an accident. It monitors temperature and movement, performing a vital sign check every 15 minutes. Family members can even remotely check on the welfare of their relatives by logging onto a secure website.

## Neanderthals flavoured their food

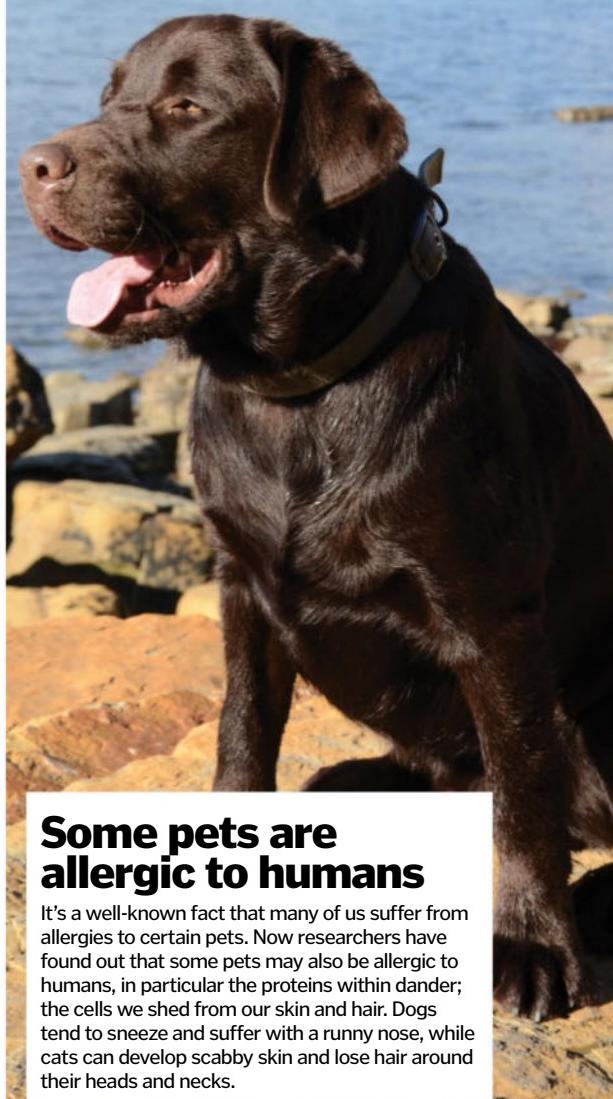
When you think of a Neanderthal, you're likely to picture a brutish early human, tearing chunks of meat straight off the bone. It turns out they were better chefs than we first thought. By analysing their teeth, scientists have shown that Neanderthals actually flavoured their food with wild herbs, including camomile and yarrow. Some anthropologists also believe they cooked stews inside animal skins.





## A super-efficient seaplane takes off

The CYG-11 is a new prototype seaplane from Chinese developers, which takes advantage of the 'wing-in-ground effect'. This is where the proximity of the aircraft's wings to the ground increases lift and decreases drag. Designed to fly or 'float' only three metres (9.8 feet) above the ocean's surface, this aircraft could be used for coastal defence, customs patrols and maybe even public transport in the future.



## Some pets are allergic to humans

It's a well-known fact that many of us suffer from allergies to certain pets. Now researchers have found out that some pets may also be allergic to humans, in particular the proteins within dander; the cells we shed from our skin and hair. Dogs tend to sneeze and suffer with a runny nose, while cats can develop scabby skin and lose hair around their heads and necks.



## Female primates are better at DIY

New research has shown that female primates are better than males at DIY. It appears female chimps are more likely to use tools to help them hunt, while males prefer to use their hands to capture their prey. Regardless of whether you believe in the human stereotype of men's DIY superiority, it's interesting to see the opposite is true for our closest living relatives.

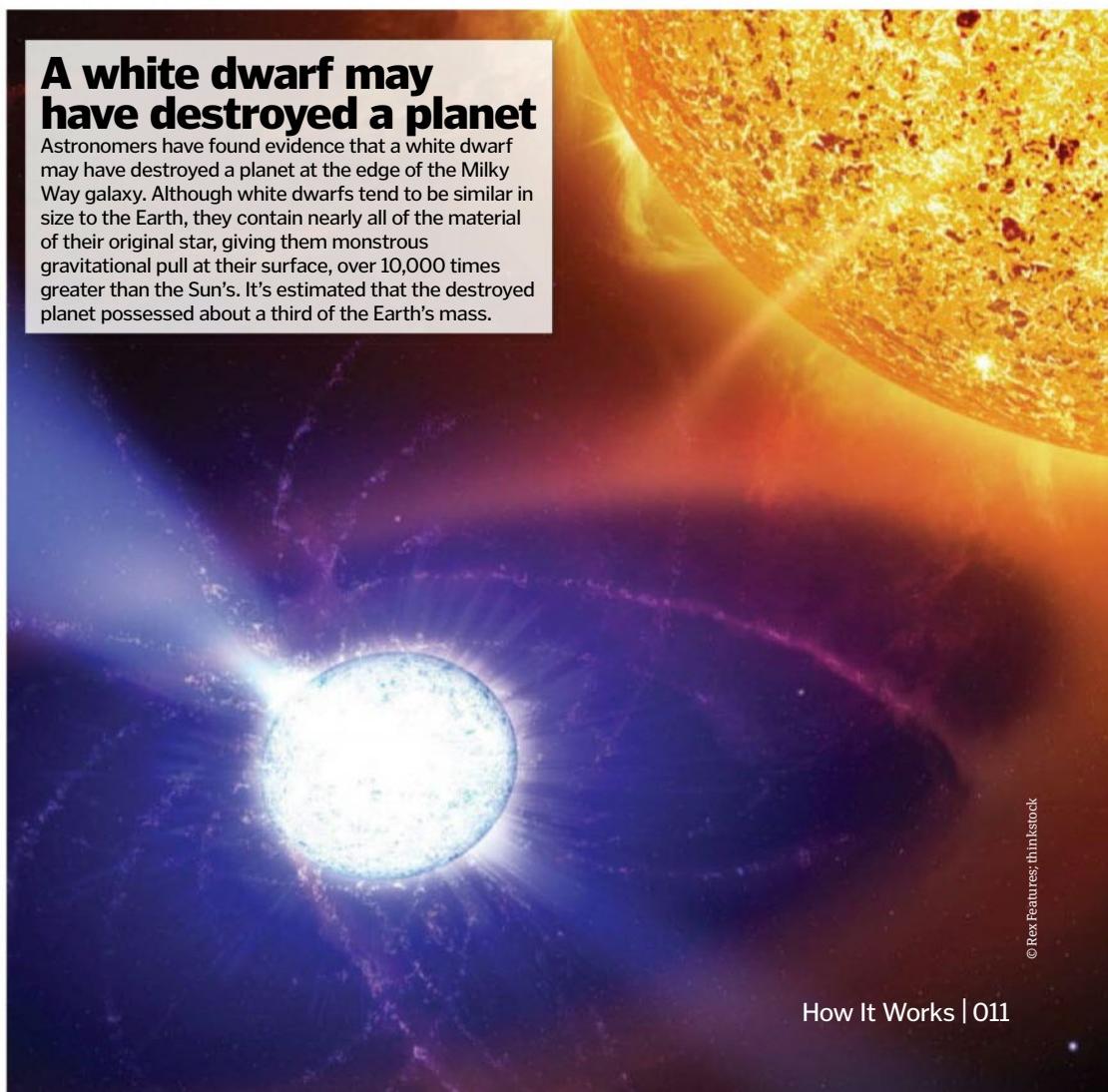
## Why cooked lobsters are a different colour

Until now, the reason why a lobster's shell changes from blue to an orange-red during cooking was not completely understood. It is caused by heat breaking down crustacyanin, a protein that suppresses the orange-red hue of a chemical called astaxanthin, which remains in the shell after cooking.



## A white dwarf may have destroyed a planet

Astronomers have found evidence that a white dwarf may have destroyed a planet at the edge of the Milky Way galaxy. Although white dwarfs tend to be similar in size to the Earth, they contain nearly all of the material of their original star, giving them monstrous gravitational pull at their surface, over 10,000 times greater than the Sun's. It's estimated that the destroyed planet possessed about a third of the Earth's mass.



**01** THE WORD 'DINOSAUR' MEANS TERRIBLE LIZARD

The word 'dinosaur' was first used in 1841 by biologist Sir Richard Owen. It is from the Greek word 'deinos', meaning terrible or great, and 'sauros', meaning lizard.

Camarasaurus

Late Jurassic  
North America**02** DINOSAURS WERE NOT LIZARDS

Despite being named 'terrible lizards', dinosaurs were anatomically very different from other reptiles and are not that closely related.

Monolophosaurus

Mid Jurassic  
China

FACT 3  
**200** TONS  
NO DINOSAUR EVEN  
CAME CLOSE TO THE  
WEIGHT OF A BLUE  
WHALE

# 101 GIGANTIC FACTS ABOUT

# DINOSAURS

THE TRUTH BEHIND  
NATURAL HISTORY'S  
BEHEMOTHS

**04** CAVE MEN NEVER MET THE DINOSAURS

The reign of the dinosaurs came to an end 66 million years ago, but humans have only been around for 200,000 years. Our ancestors did not share a world with the dinosaurs, but they did encounter sabre-toothed cats and woolly mammoths.

Deinonychus

Early Cretaceous  
North America

Sauropteryx

Early Cretaceous  
North America

Corythosaurus  
Late Cretaceous  
North America

05 NO ONE KNOWS  
WHAT COLOUR  
DINOSAURS REALLY WERE

The coloured pictures of dinosaurs seen in textbooks are guesswork based on what we know about animals today, but scientists have analysed melanosomes (pigment cells) found in fossils and are piecing together their real colours.

FACT 6  
**5cm**  
STEGOSAURUS HAD  
A BRAIN THE SIZE  
OF A PLUM

Stegosaurus  
Late Jurassic  
North America

07 TRICERATOPS HAD  
UP TO 800 TEETH

Triceratops might be known for their horns, but these icons of the Cretaceous period had another special feature. They had hundreds of teeth, stacked on top of one another in groups of three to five in piles called 'dental batteries'.

Dimetrodon  
Early Permian  
North America

08 NOT ALL PREHISTORIC REPTILES  
WERE DINOSAURS

Over 230 million years ago, the Earth was dominated by large mammal-like reptiles like Dimetrodon and Lystrosaurus. They might look like dinosaurs, but they are actually more closely related to modern mammals.

# A BRIEF HISTORY OF DINOSAURS

Around 230 million years ago, the world was a very different place. The land was joined together to form a single continent, and the dominant animals were reptiles. These enormous animals included some of the largest creatures to have ever walked the Earth.

Over the course of their 165-million-year reign, the world underwent tremendous changes. The landmasses tore apart, and the climate became cooler and wetter. Seas appeared and disappeared, and plants started to dominate the land, covering the landscape in ferns, horsetails and conifers.

Over the course of the Mesozoic Era, dinosaurs came to inhabit every landmass, diversifying into a huge variety of weird and wonderful shapes. All dinosaurs are thought to be descended from a small two-legged ancestor weighing just a few kilograms, but some evolved claws for grasping, others had bony armour, spikes, scales and horns, and some became enormous four-legged giants with extremely long necks and tails. Over time, dinosaurs became larger and larger on average.

These enormous animals were reliant on the environment for their survival, but 66 million years ago disaster struck. Around this time, a colossal asteroid struck the Earth, volcanic eruptions spewed ash into the sky, and high oxygen levels fuelled fires on the ground. The sea level dropped and 75 per cent of life on the planet perished.

Mammals could keep warm, were able to reproduce more rapidly and could burrow underground, so they quickly came to dominate the post-dinosaur world. Although the large dinosaur species died out in the mass extinction event, some of the theropods survived. They had evolved to become smaller over time, so were better able to cope with the changing environment. There is mounting evidence that birds descended from these adaptable dinosaurs.

The dinosaurs are some of the most successful animals to have ever lived on Earth. They dominated the planet for over 150 million years, and despite suffering catastrophic losses at the time of the mass extinction event 66 million years ago, their ancestors are still among us and still manage to colonise every corner of the planet.

FACT 9  
**3.5KG**  
COMPSOGNATHUS,  
ONE OF THE SMALLEST  
DINOS, WAS ONLY JUST  
LARGER THAN A  
CHICKEN

Compsognathus  
Late Jurassic  
Europe





# SAUROPODS

These long-necked giants are among the largest animals to have ever lived

## 10 SAUROPODS WERE HUGE HERBIVORES

The four-legged dinosaurs with long tails and necks are known as sauropods. The most common were Diplodocus and Camarasaurus.

## 13 TITANOSAURS LAID THE LARGEST EGGS

The larger an egg is, the thicker its shell has to be. Even the monstrous titanosaurs had to lay relatively small eggs so that oxygen and carbon dioxide could cross over the walls of the shell.

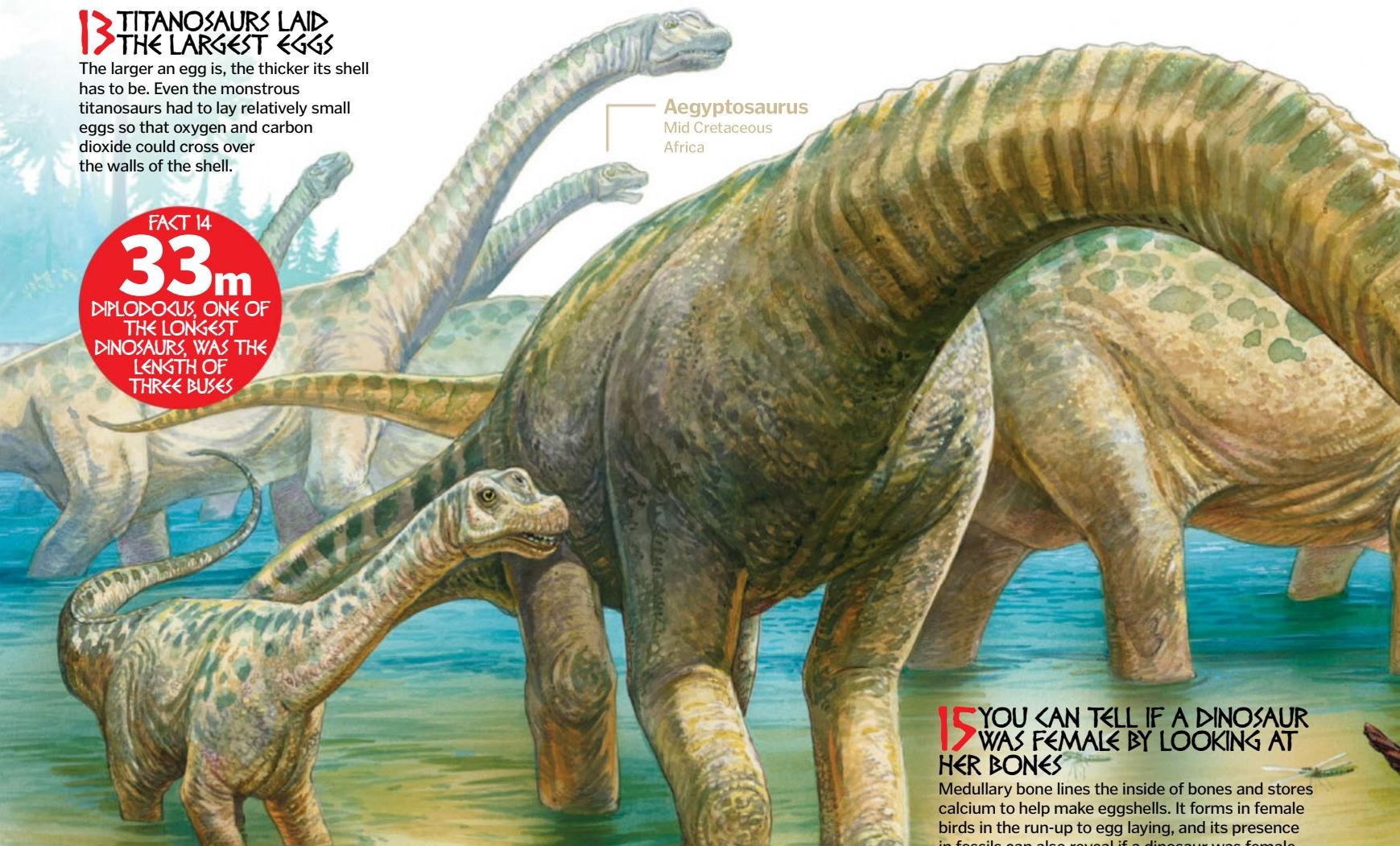
**FACT 14**  
**33m**  
 DIPLODOCUS, ONE OF THE LONGEST DINOSAURS, WAS THE LENGTH OF THREE BUSES

## 11 DIPLODOCUS HAD 15 VERTEBRAE IN ITS NECK

At least, we think it did – there are very few complete specimens. For comparison, a human has seven neck vertebrae.

## 12 SAUROPODS DID NOT LIVE IN WATER

Early ideas about how sauropods like Diplodocus lived portrayed them walking underwater like hippos. They had nostrils on the top of their heads, and scientists thought they would use their necks like snorkels. However, with large bodies, the crushing weight of water would have prevented them from breathing, and we now know they lived on land.



## 22 HADROSAURS HAD DUCK-LIKE BILLS

Hadrosaurs were the first dinosaurs found in North America, and since the 19th century, hundreds have been unearthed. These herbivores had a very distinctive appearance, with duck-like beaks adapted for clipping vegetation, and crested heads that might have been helped to transmit sounds over long distances.



## 23 ORNITHOMIMIDS LOOKED AND LIVED LIKE OSTRICHES

Ornithomimid means 'bird mimic', and these two-legged dinosaurs really do look familiar. They had long, muscular legs, large, rounded bodies and long necks with small heads. Like modern ostriches, these dinosaurs were extremely fast on their feet.



## 24 DINOSAURS DIDN'T HAVE TWO BRAINS

Stegosaurus had a tiny brain, but at the base of its spine there was an enlarged space. Scientists once thought it might have housed a second, larger brain to control its legs, but this idea has been discredited as birds have a similar opening to store the energy-rich substance glycogen.



## 25 PACHYCEPHALOSAURS HAD THICK SKULLS

Pachycephalosaurus means 'thick-headed lizard'. The bone at the top of their skull could be up to 25cm (10in) thick, and their faces were covered in bumps and spikes. These dramatic features could have been for fighting, or they might just have been for show, like the antlers on modern deer.

## 16 ANKYLOSAURUS WAS ONE OF THE LAST SURVIVING DINOSAURS

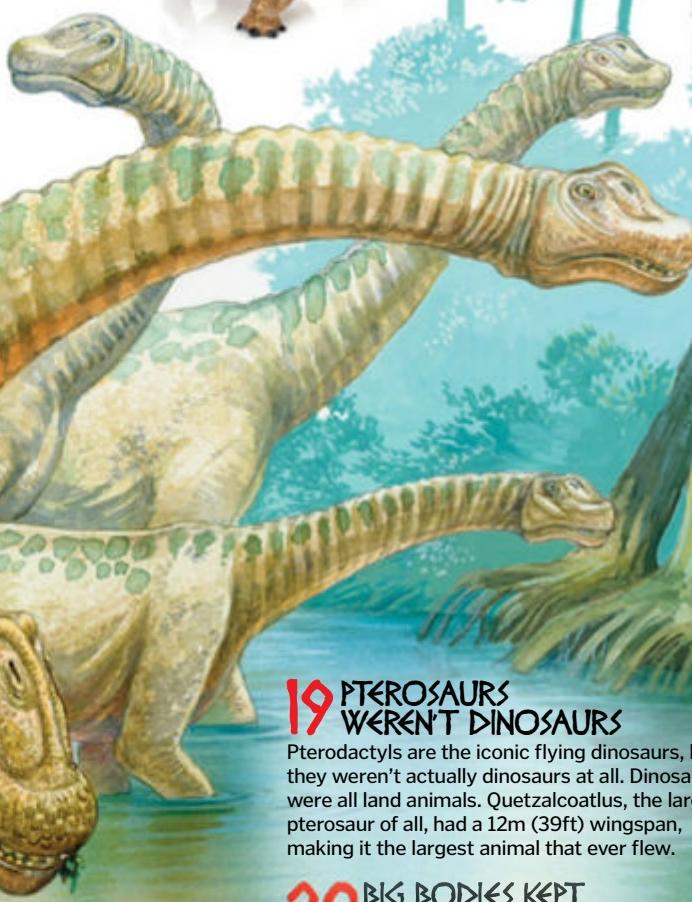
These heavily armoured dinosaurs had clubbed tails, weighed over 4,000kg (8,818lb) and were covered in bony plates. They were extremely tough, and no predator could tackle a full-grown adult.



FACT 18  
**18.5m**  
SAUROPODON WAS ABOUT THREE TIMES TALLER THAN A GIRAFFE

## 17 HERDS OF DINOSAURS WERE FOSSILISED TOGETHER

At a bonebed in Alberta, Canada, at least 27 ceratopsids with frilled heads and horns were found buried together.



## 21 THE SEA LEVEL DROPPED AS THE DINOSAURS WENT EXTINCT

At around the time the dinosaurs went extinct, the sea level fell by 150m (492ft) in just 1 million years, and inland seas dried up.



Sinornithosaurus

Early Cretaceous  
China

## 26 DINOSAURS HAD FEATHERS

Despite what you might see in textbooks, museums and even in this article, we now know that most dinosaurs were not all scaly and bald. We have known for a while that the two-legged theropods had feathers, but in 2014 a very distantly related beaked dinosaur found in Siberia was also found to have feathers, suggesting scales were replaced early in dinosaur evolution.

## 19 PTEROSAURS WEREN'T DINOSAURS

Pterodactyls are the iconic flying dinosaurs, but they weren't actually dinosaurs at all. Dinosaurs were all land animals. Quetzalcoatlus, the largest pterosaur of all, had a 12m (39ft) wingspan, making it the largest animal that ever flew.

## 20 BIG BODIES KEPT DINOSAURS WARM

This process is known as 'thermal inertia'. The larger the body of an animal, the lower the surface-to-volume ratio – preventing heat escaping from the skin.



## 27 CERATOPSIANS HAD HORNED FACES

The most famous ceratopsian is Triceratops, but there were other dinosaurs with horns and frills. These huge herbivores started to appear around 160 million years ago, and it is thought the frill was used as protection against predators, to impress potential mates and as a radiator to get rid of excess heat.



## NESTS & EGGS

### 28 ALL DINOSAURS LAID EGGS

Dinosaurs all reproduced by laying eggs like modern-day birds, and some of the hatchlings were thousands of times smaller than the full-grown adults.

### 29 SOME DINOSAURS CARED FOR THEIR YOUNG

Adult Psittacosaurus have been found alongside the fossilised remains of their young, and the bones of older babies have been found in the nests of Maiasaura, indicating that they probably helped to raise their young.

### 30 THE LARGEST DINOSAUR EGG WAS OVER 60CM LONG

The largest dinosaur eggs were found in Mongolia in the 1990s, and measured around 45cm (17.7ft) across. Compared to the size of the adults, they are still surprisingly small.

### 31 SOME OF THE BEST DINOSAUR FOSSILS ARE BABIES

A 113-million-year-old fossilised baby dinosaur found in Italy still contains traces of preserved soft tissue, including intestines and tail muscles.

### 32 BABY DINOSAURS GREW RAPIDLY

Sauropods like Diplodocus weighed a tiny 5kg (11lb) at birth, and grew to 10,000 times their size within just 30 years. Fossilised embryos show sauropod bones filled with blood vessels, bringing nutrients to allow rapid growth.

### 33 THERE ARE TWO MAIN TYPES OF DINOSAUR EGG

Dinosaur eggs can be divided into two main categories – spheroidal and elongated. Rounder eggs were laid by herbivores such as sauropods, while elongated, bird-like eggs were laid by theropods.

### 34 OVIRAPTORS DIDN'T STEAL EGGS

The name 'Oviraptor' means egg thief, but these dinosaurs weren't criminals. They were actually devoted parents, and fossilised nests found in Mongolia show they arranged their eggs in spiral layers.



# TYRANNOSAURUS REX

**35** YOU PROBABLY COULDN'T OUTRUN A TYRANNOSAURUS

Computer simulations of T-rex running suggest that if it had a top speed of around 29km/h (18mph). Not quite fast enough to catch up with a car, like in *Jurassic Park*, but quick enough to catch any human that's not an athlete.

## HEAD

It measured 1.5m (4.9ft) long, and had eye and nose cavities. The skull was of thick and heavy bone, although in some points it was pretty flexible.

**36** THE LARGEST FOSSIL IS CALLED SUE

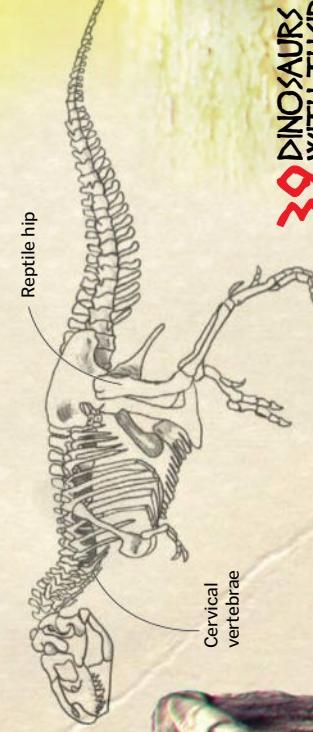
Complete dinosaur fossils are incredibly rare, but there is one T-rex specimen that stands out from the rest. Sue is over 12.8m (40ft) long and stands over 3.9m (13ft) high. She is on display at the Chicago Field Museum and is the most complete specimen ever recovered.

**37** STEGOSAURUS NEVER MET TYRANNOSAURUS

Despite being depicted together, these two would never have been in the same place at the same time. Stegosaurus lived during the Jurassic period and went extinct around 80 million years before T-rex first appeared at the end of the Cretaceous period.

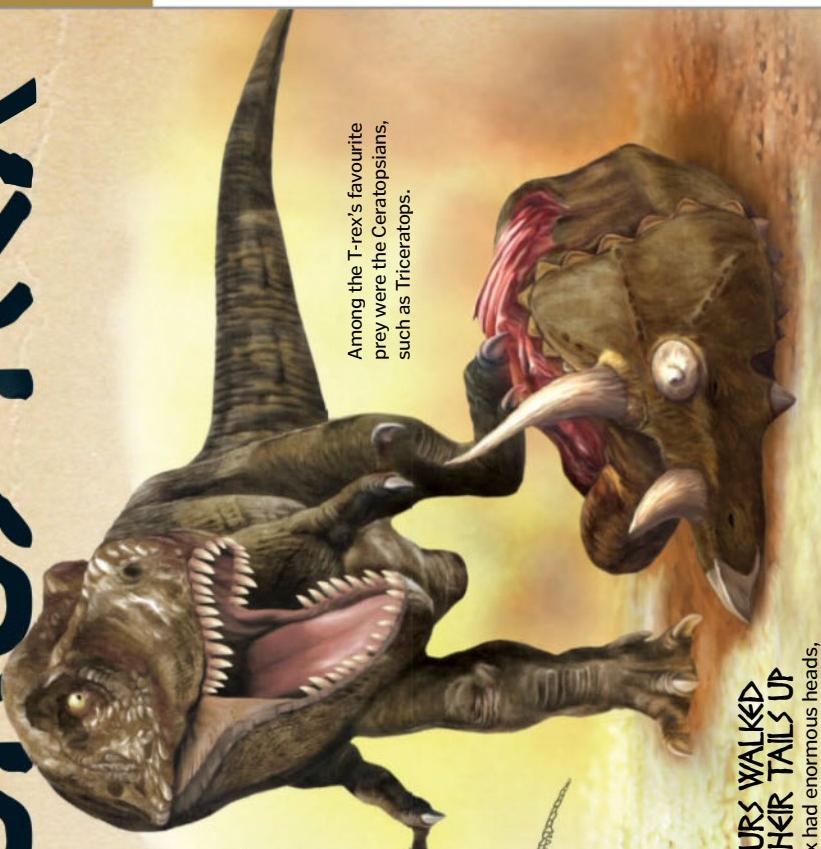
## 38 SOME DINOSAURS HAD A WISHBONE

The 'V'-shaped wishbone you find in your Sunday roast is also present in meat-eating theropods such as T-rex.



**39** DINOSAURS WALKED WITH THEIR TAILS UP

Dinosaurs like T-rex had enormous heads, and used their tails as a counterweight, holding them up for balance.



Among the T-rex's favourite prey were the Ceratopsians, such as Triceratops.

**40** THE MEAT-EATING DINOSAURS WERE ALL THEROPODS

T-rex, Allosaurus and Deinonychus belonged to a group of dinosaurs known as theropods. Some members of this group are the largest carnivores ever to have walked the Earth.

DATA SHEET



GENUS *Tyrannosaurus*  
CLASSIFICATION Theropoda;  
Coelurosauria; Tyrannosauroidea  
LENGTH 12.5m  
WEIGHT 5,000kg  
DIET Carnivorous

41 T-REX HAD  
THE SIZE  
OF BANANAS

The largest *Tyrannosaurus rex* teeth measured 30cm (12in) in length. There has been much debate as to what they were used for, but scientists generally agree that T-rex was both a hunter and a scavenger. Broken T-rex teeth found in the fossilised tailbones of Hadrosaurs indicate that hunts weren't always successful.

42 T-REX HAD  
STRONGER  
ARMS THAN A  
HUMAN

T-rex is often ridiculed for its stumpy little arms, but they were much stronger than you might imagine. They were used for grasping prey, could move rapidly and were capable of lifting around 200kg (440lb), more than three times as much as an adult man.



PHYLOGENETIC TREE



44 THERE WAS A DINOSAUR  
CALLED 'IRRITATOR'

Irritator was a fish-eating spinosaurus first described in 1996. It got its name because the fossilised head had been modified by fossil hunters with car body filler to make it look more impressive. The scientists understandably found this very irritating.

45 DINOSAURS  
DIDN'T LIVE  
IN THE SEA

Dinosaurs were land animals and were not closely related to the famous sea-dwelling Plesiosaur, but Spinosaurus was semi-aquatic and could run along the riverbed.

© Sol 90; Nobuyamura; H. Zell; Thinkstock

43 THE MOST EXPENSIVE  
FOSSIL IS WORTH MORE  
THAN \$8 MILLION

The famous *Tyrannosaurus rex* fossil known as Sue fetched \$8.36 million at auction back in 1997 and is likely to be worth significantly more than that today.

FOUND IN...

The *Tyrannosaurus rex* was found in what is now North America, just like its cousins the *Daspletosaurus*, the *Gorgosaurus* and the *Albertosaurus*. The *Tarbosaurus* and the *Guanlong*, a primitive tyrannosaur of the Jurassic period, were discovered in Asia.



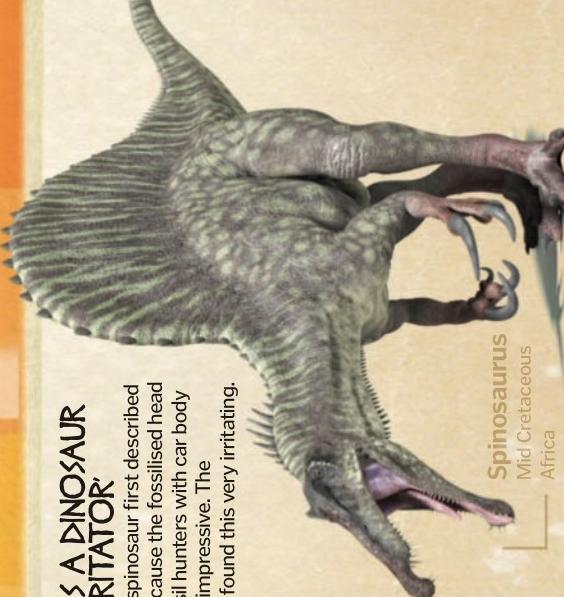
47 ARCHAEOPTERYX IS  
THE FIRST FOSSIL  
EVIDENCE OF EVOLUTION

*Archaeopteryx* was the first feathered dinosaur to be discovered, linking birds and dinosaurs. The breakthrough came in 1861, just two years after Charles Darwin published his theory of evolution.



46 NO DINOSAUR  
COULD FLY

Dinosaurs were all land-dwelling reptiles, and despite the fact that they are the ancestors of modern birds, none of them could fly.



48 DINOSAURS WERE  
NEITHER WARM NOR  
COLD BLOODED

It was long thought that dinosaurs were cold blooded, like reptiles, but new evidence suggests that they were mesothermic – able to burn energy to make some body heat, but not warm blooded like mammals.

48 DINOSAURS WERE  
NEITHER WARM NOR  
COLD BLOODED



# CLASSIFICATION

Dinosaurs can be split into two major groups, with many more subdivisions

## 49 THE MEAT-EATING DINOSAURS WALKED ON TWO FEET

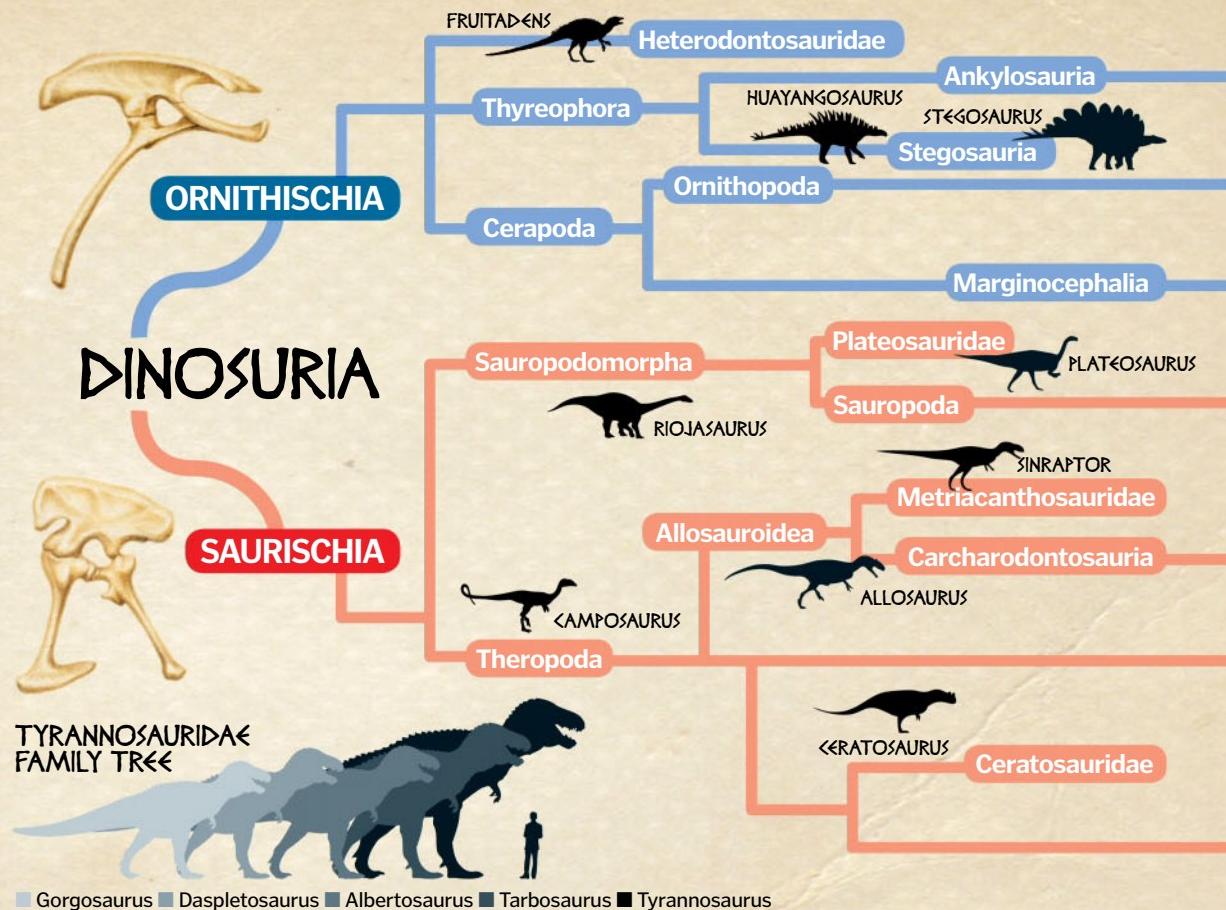
All the carnivorous dinosaurs were theropods (although not all theropods were carnivores) and walked upright on their two hind legs. They typically had hollow bones, three main fingers on each hand and foot, and sharp, curved teeth and claws used for hunting and eating.

## 50 DINOSAURS EITHER HAD LIZARD HIPS OR BIRD HIPS

Dinosaurs can be divided into two major groups based on their hipbones. The Ornithischia, or 'bird-hipped' dinosaurs had a pubic bone that pointed toward the tail, and the Saurischia, 'lizard-hipped' dinosaurs pointed toward the head. Interestingly, birds evolved from lizard-hipped dinosaurs.

## 51 MOST DINOSAURS ATE PLANTS

Dinosaurs are often portrayed as fearsome hunters, but the majority of species were herbivores. Even some of the ferocious-looking theropods actually ate plants and used their sharp claws for digging.



## 56 DINOSAURS LIVED DURING THE MESOZOIC ERA

Dinosaurs ruled the Earth for 165 million years, in a time period known as the Mesozoic Era. This era can be split into three periods, Triassic, Jurassic and Cretaceous

## 57 DINOSAURS FIRST APPEARED 230 MILLION YEARS AGO

Dinosaurs evolved during the Triassic period, between 250 and 200 million years ago. The warm, dry conditions were perfect for breeding reptiles.

## 58 VOLCANIC ERUPTIONS CONTRIBUTED TO THE EXTINCTION OF THE DINOSAURS

Huge lava flows are present in the fossil record for about 500,000 years before the extinction of the dinosaurs, and many scientists think eruptions contributed to their extinction by filling the air with a thick cloud of ash.

## 59 EARLY DINOSAURS LIVED ON THE CONTINENT OF PANGAEA

When dinosaurs first appeared, the landmasses of the Earth were joined into a supercontinent called Pangaea. This later fractured into two continents - Laurasia and Gondwana.

**Camposaurus**  
Late Triassic  
North America

**Riojasaurus**  
Late Triassic  
South America

**Torvosaurus**  
Late Jurassic,  
North America,  
Europe

**Apatosaurus**  
Late Jurassic  
North America

**Stegosaurus**  
Late Jurassic  
North America,  
Europe

TRIASSIC 252–201 MILLION YEARS AGO

JURASSIC 201–145 MILLION YEARS AGO

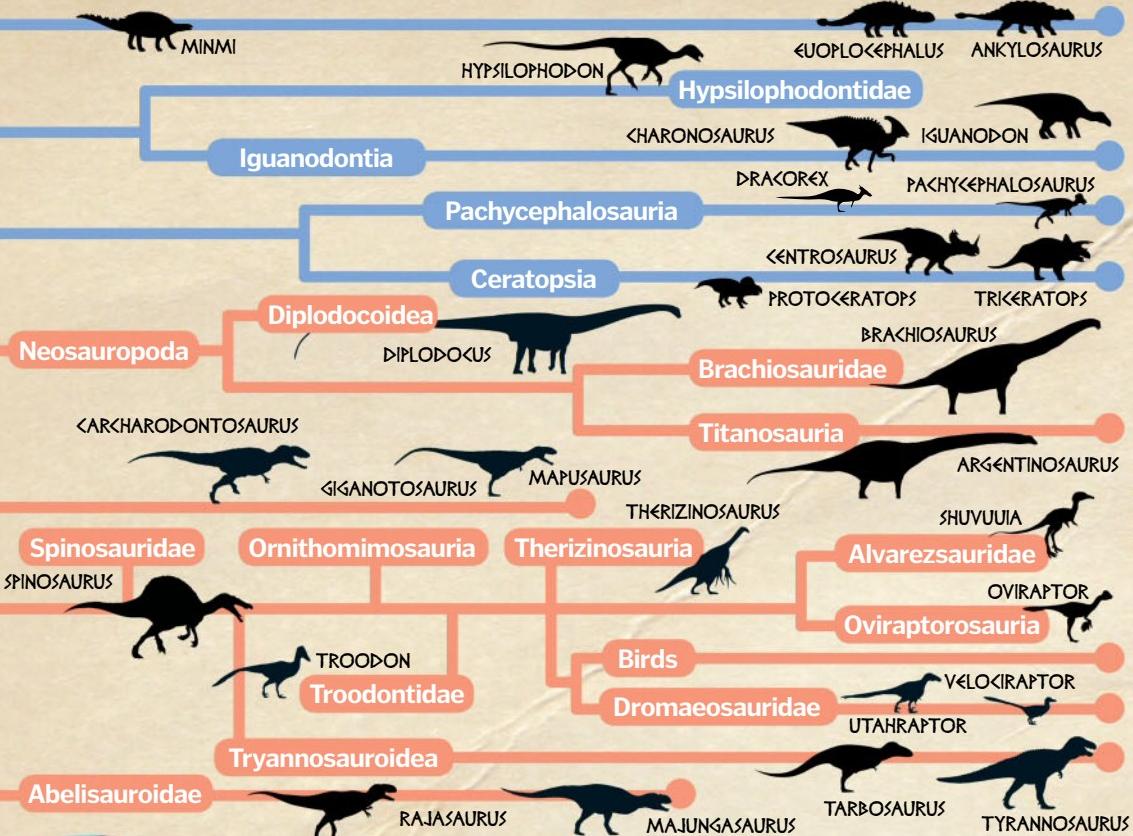
**DID YOU KNOW?** A theropod known as Concavenator had a hump on its back like a camel

## 52 THERE WERE MORE THAN 700 SPECIES OF DINOSAUR

To date, over 700 species of dinosaur have been identified, but only around 300 have been confirmed as entirely unique. There are more yet to be found, so this number will continue to change.

## 53 THERE ARE HUNDREDS OF DINOSAURS YET TO BE FOUND

It is estimated that we have only found around a tenth of the dinosaur species that ever existed. Some are buried in rocks we cannot reach, while others lived in areas where conditions did not favour fossil formation.



## 54 THERE WERE FEWER DINOSAUR SPECIES THAN WE THOUGHT

Hundreds of species of dinosaur have been named, but very few baby dinosaurs have ever been found. Scientists have reviewed the evidence again and have found that some smaller species might actually be the babies of larger species, and that as they grew their head and body shapes changed.



## 55 DINOSAURS ARE STILL ALIVE TODAY

In the 19th century the fossilised remains of a feathered dinosaur called Archaeopteryx were discovered, and since then evidence linking dinosaurs to birds has stacked up. It is thought that early birds started to evolve from the carnivorous theropods in the late Jurassic, and a few managed to survive the mass extinction, giving rise to the bird species we see today.

© Thinkstock/Science Photo Library

## 60 SEA LEVELS WERE AT AN ALL-TIME HIGH IN THE CRETACEOUS

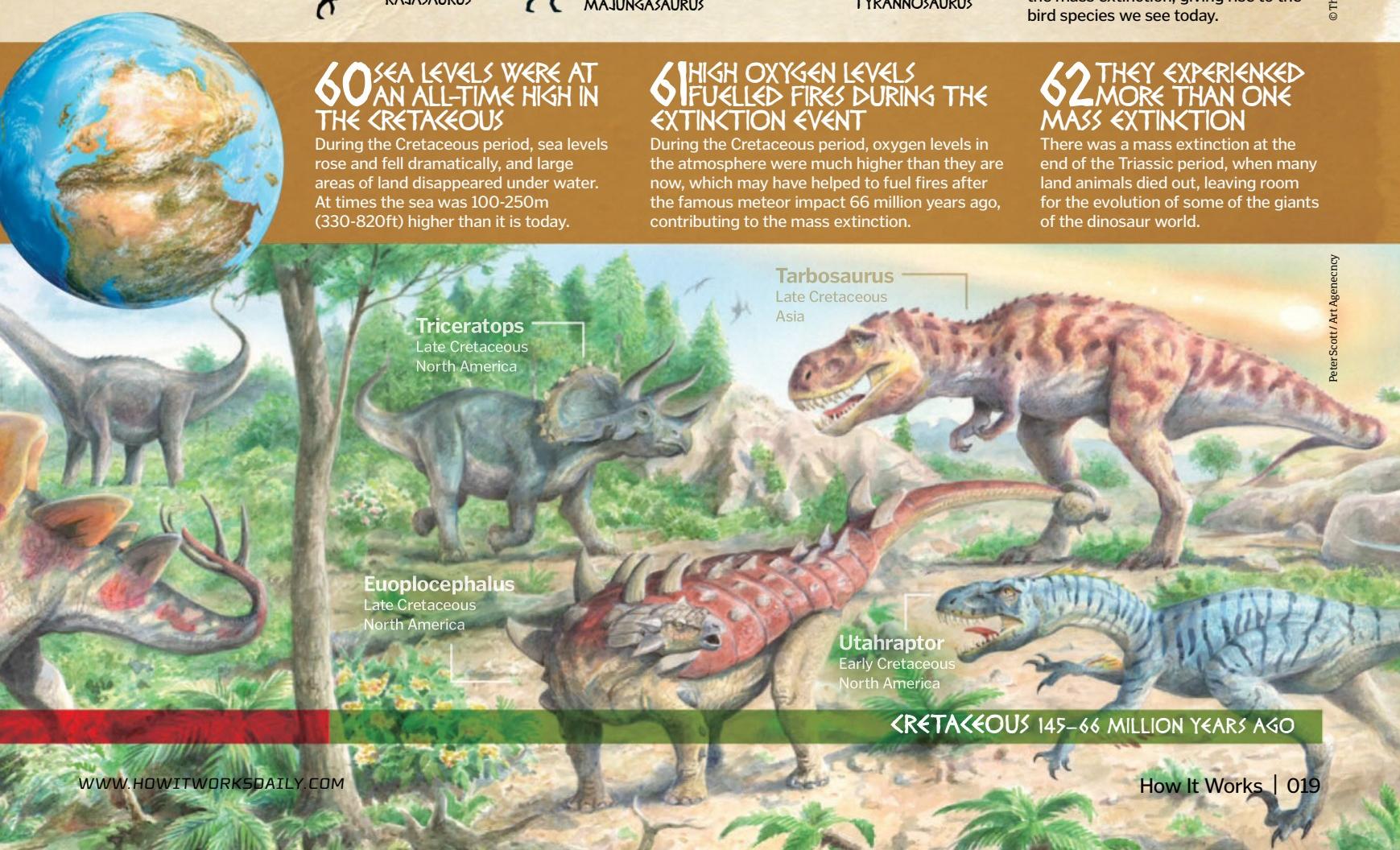
During the Cretaceous period, sea levels rose and fell dramatically, and large areas of land disappeared under water. At times the sea was 100-250m (330-820ft) higher than it is today.

## 61 HIGH OXYGEN LEVELS FUELLED FIRES DURING THE EXTINCTION EVENT

During the Cretaceous period, oxygen levels in the atmosphere were much higher than they are now, which may have helped to fuel fires after the famous meteor impact 66 million years ago, contributing to the mass extinction.

## 62 THEY EXPERIENCED MORE THAN ONE MASS EXTINCTION

There was a mass extinction at the end of the Triassic period, when many land animals died out, leaving room for the evolution of some of the giants of the dinosaur world.





Minmi  
Early Cretaceous  
Australia

### 63 ARMoured DINOSAURS ARE KNOWN AS 'THYREOPHORA'

Stegosaurus and Ankylosaurus are famous for their armour plating and were members of a group of dinosaurs called Thyreophora. Ankylosauria were the most heavily armoured and had bony plates, spikes and clubbed tails.

### 64 DINOSAUR'S LEGS ARE POSITIONED BEHIND THEIR BODIES

Crocodiles and lizards walk with their legs out to the sides, but dinosaurs have their legs underneath their bodies, allowing them to run faster.

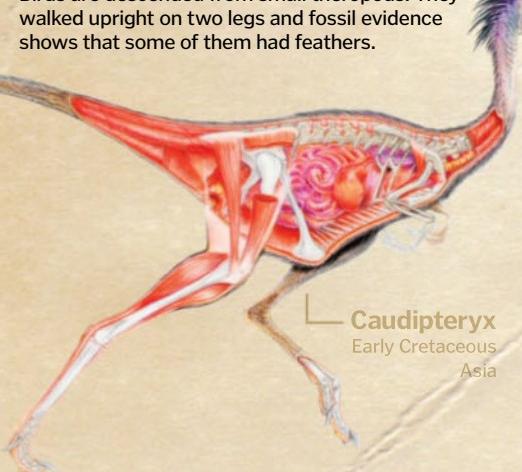


### 65 SOME DINOSAURS SWALLOWED ROCKS

Many plant-eating dinosaurs have been found with groups of rounded stones inside their ribcages, indicating they swallowed stones to aid digestion, like modern birds.

### 66 SOME DINOSAURS HAD A MIXTURE OF DINOSAUR-LIKE AND BIRD-LIKE FEATURES

Birds are descended from small theropods. They walked upright on two legs and fossil evidence shows that some of them had feathers.



Caudipteryx  
Early Cretaceous  
Asia

### 67 DINOSAURS LIVED IN A CHANGING WORLD

Around 250 million years ago, all of Earth's landmasses were joined in a supercontinent known as Pangaea. During the reign of the dinosaurs, this landmass split apart, first into two and then into the seven continents we see today.

### 68 PALEONTOLOGISTS STUDY FOSSILS

Scientists that study dinosaur remains are known as palaeontologists. Anthropologists study human remains, and archaeologists study artefacts.

### 69 SOME HERBIVORES HAD SELF-SHARPENING TEETH

As their jaws closed, the teeth of some plant-eating dinosaurs would grind against each other, wearing the surface into a sharp point.

### 70 HADROSAURS HAD THE MOST TEETH

The duck-billed dinosaurs had up to 50 rows of teeth stacked on top of one another, making a total of over 1,000.





## 71 DINOSAURS HAD GIANT FLEAS

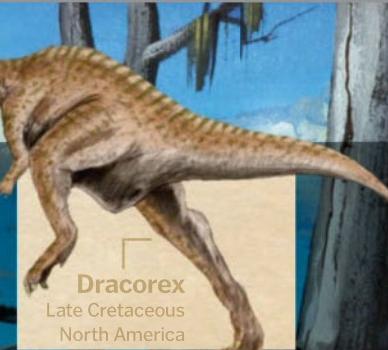
Fossilised remains reveal that dinosaurs in the Cretaceous and Jurassic were hosts to giant flea-like insects measuring ten times the size of modern fleas.

## 72 ORNITHOPODS WALKED ON TWO LEGS

Dinosaurs like Iguanodon and the duck-billed Hadrosaurs walked upright on two legs, and lived in herds like modern-day antelope.

## 73 ONE DINOSAUR IS NAMED AFTER THE HARRY POTTER BOOKS

*Dracorex hogwartsia* ("dragon king of Hogwarts") was a pachycephalosaur with a large bulge on its forehead and a dragon-like spiked frill.



**Indosuchus**  
Late Cretaceous  
India



## 74 DINOSAURS SURVIVED FOR 165 MILLION YEARS

People often think of the dinosaurs as being evolutionary failures, but they survived for a staggering 165 million years, far more impressive than the 200,000 years managed so far by humans.

FACT 75  
**35m**  
ARGENTINOSAURUS  
WAS LONGER THAN  
A BLUE WHALE

**Compsosuchus**  
Late Cretaceous  
Asia

## 77 MANY DINOSAURS HAD HOLLOW BONES

Birds have hollow bones, which helps to keep their weight down for flight and enables a unique way of breathing – sauropods and theropods had hollow bones too.

## 78 LOTS OF DINOSAURS WERE SMALLER THAN US

*Diplodocus*, *Triceratops*, *T-rex* and *Stegosaurus* were all enormous, but many of the two-legged raptors and some of the herbivores were smaller than we are.



# HUNTING DINOSAURS

Fossils have been found on every continent on Earth...

## 79 NORTH AMERICA HAS EXCAVATED THE MOST DINOSAUR FOSSILS

North America, Argentina and China have more than their fair share of dinosaur fossils. Areas with desert-type environments prevented the build-up of thick layers of plants, leaving the remains easier to find under sand and rock.



## 80 THE FIRST DINOSAUR FOSSIL WAS FOUND IN ENGLAND

The first dinosaur to be scientifically documented was Megalosaurus, formally named by William Buckland in 1824. The fossils were found in a quarry in Oxford.

## 81 FOSSILISED DINOSAUR HIGHWAYS ALLOW US TO RETRACE ANCIENT STEPS

Enormous mudflats captured the imprints of dinosaur footprints, and some were preserved as fossils. Utah in the United States is particularly famous for its dinosaur trackways, which can be found on what used to be an ancient muddy floodplain.



## 82 NEW DINOSAURS ARE DISCOVERED EVERY YEAR

There are hundreds of dinosaur fossils still to be discovered, and a new dinosaur is found and named approximately every seven weeks.

## 83 CHICXULUB CRATER MARKS THE ASTEROID IMPACT THAT KILLED THE DINOSAURS

Chicxulub crater in Mexico is a 66 million-year-old, 180km (112mi)-wide impact created by a 10km (6mi)-wide asteroid. It is thought to represent the aftermath of the impact that killed the dinosaurs. In 2016, scientists plan to drill into the crater to learn more about its history.



## 84 DINOSAUR BONES CAN BE RECOGNISED BY DISTINCTIVE SKULL HOLES

All dinosaurs have the same basic skull, with two holes for jaw muscles behind the eye and an air socket between the eyes and nose.



CANDELROS FORMATION  
Argentina



## 85 DINOSAUR BONES CAN BE AGED BY RADIOMETRIC DATING

Carbon dating doesn't work on dinosaur bones, so scientists estimate the age of fossils by measuring radioactive isotopes in the surrounding rocks.

## 95 DINOSAURS WEREN'T THE FIRST REPTILES TO RULE THE EARTH

Around 300 million years ago amphibians dominated the planet, but as the climate got warmer, reptiles took over. There were the 'bowl lizards' or pelycosaurs, mammal-like reptiles called therapsids, and archosaurs, from which dinosaurs, crocodiles and pterosaurs eventually evolved.

## 96 DINOSAURS LIVED FOR UP TO 300 YEARS

Paleontologists estimate the large dinosaurs had life spans ranging from 75 to 300 years. However, these estimates were made based on information we have about cold-blooded animals – if they were warm-blooded they would have had shorter lives.

## 97 TROODONS WERE PROBABLY THE CLEVEREST DINOSAURS

Troodons lived around 77 million years ago and were about two metres (6.6 feet) long. They were carnivores, walked on two legs and had relatively large brains for their body size. They are also thought to be related to modern birds.

## 98 AMBER INSECTS DON'T CONTAIN DINOSAUR DNA

Jurassic Park is based on the idea that you could extract dinosaur DNA from blood preserved inside the bodies of mosquitoes encased in amber. Unfortunately, despite several attempts to recover DNA from preserved insects, it seems as though it doesn't actually survive inside the amber.



Megalosaurus  
Mid Jurassic  
Europe

**86** MORE THAN 100 DIFFERENT DINOSAURS LIVED IN BRITAIN

Britain used to form a land bridge that connected Europe to North America, and has been described as a dinosaur paradise. It was home to over 100 different species, including armoured ankylosaurs, giant sauropods and three different types of fearsome tyrannosaur.



**87** THERE'S NO ACTUAL BONE IN A DINOSAUR FOSSIL

When dinosaurs died, their bones were covered in sediment that was compressed and turned to rock. Over time, the bone itself dissolved away, leaving a bone-shaped hole in the rock, which then filled with minerals, forming a cast.



Diplodocus  
Late Jurassic  
North America

**88** MOST DINOSAUR FOSSILS WERE FOUND BY AMATEURS

There are many more amateur fossil hunters than professionals, and they can cover much more ground. The largest T-rex fossil ever was found by an amateur.

**89** THERE ARE TWO MAIN TYPES OF FOSSIL

Body fossils show the actual shape of dinosaur remains, while trace fossils show evidence of their lives, like footprints and nests.

**FACT 90**  
**77** tons  
ARGENTINOSAURUS, THE HEAVIEST DINOSAUR, WEIGHED THE SAME AS A BOEING 737



**91** FOSSILISED FOOTPRINTS TELL US HOW DINOSAURS MOVED

Preserved dinosaur tracks revealed some theropods could run at 43.5km/h (27mph).



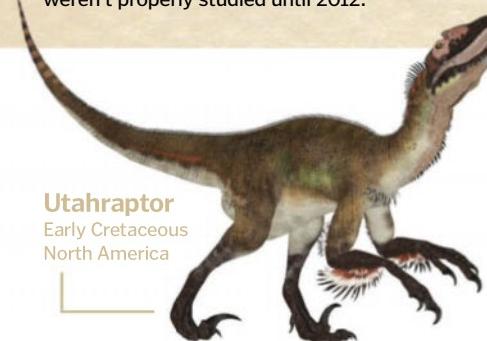
**93** THE MOST ANCIENT DINOSAUR FOSSILS WERE FOUND IN TANZANIA

One of the earliest-ever dinosaur fossils found is a 243-million-year-old dog-sized dinosaur called Nyasasaurus parringtoni. Bones from two different individuals were excavated in the 1930s, but weren't properly studied until 2012.



**94** DINOSAUR FOSSILS ARE FOUND ON ALL SEVEN CONTINENTS

Dinosaur fossils have been found in the very northern parts of Canada, right down to the frozen wastes of Antarctica.



Utahraptor  
Early Cretaceous  
North America

**99** RAPTORS WERE COVERED IN FEATHERS

Of all the dinosaurs, the most feathery were the theropods. Velociraptors were covered in a layer of feathers, and so too was T-rex. Many other dinosaurs had spiny quills or feathery stubs.

**100** MAMMALS USED TO EAT DINOSAURS

Repenomamus robustus was a 1m (3.3ft)-long mammal that lived 125 million years ago in China. One specimen was found with dinosaur remains inside it.

**101** BRONTOSAURUS MIGHT HAVE BEEN A REAL DINOSAUR AFTER ALL

Brontosaurus is famous for not being a real dinosaur – the fossils were mixed up and the head of a Camarasaurus was placed on the body of an Apatosaurus. However, in 2015, a new study of the bones revealed that Brontosaurus has a longer and thinner neck than Apatosaurus and thus might be a distinct species after all.



# What were armoured trains?

Discover how railways went to war in the 19th and 20th century

The explosion of rail travel in the 19th century changed warfare. Now armies depended upon railways to mobilise and to supply, from dispatching troops and vehicles to the front line to keeping them well-stocked with munitions, medicine and other sundries. Railways became pivotal to the war effort, so they had to be protected.

The first improvised armoured trains appeared in 1848 for use by the Austro-Hungarian army in quelling the revolutions that gripped the empire that year. Nearly two decades later they proved their strategic worth in the American Civil War of 1861 to 1865 when armoured trains protected the Union-held rail lines of Baltimore from Confederate saboteurs.

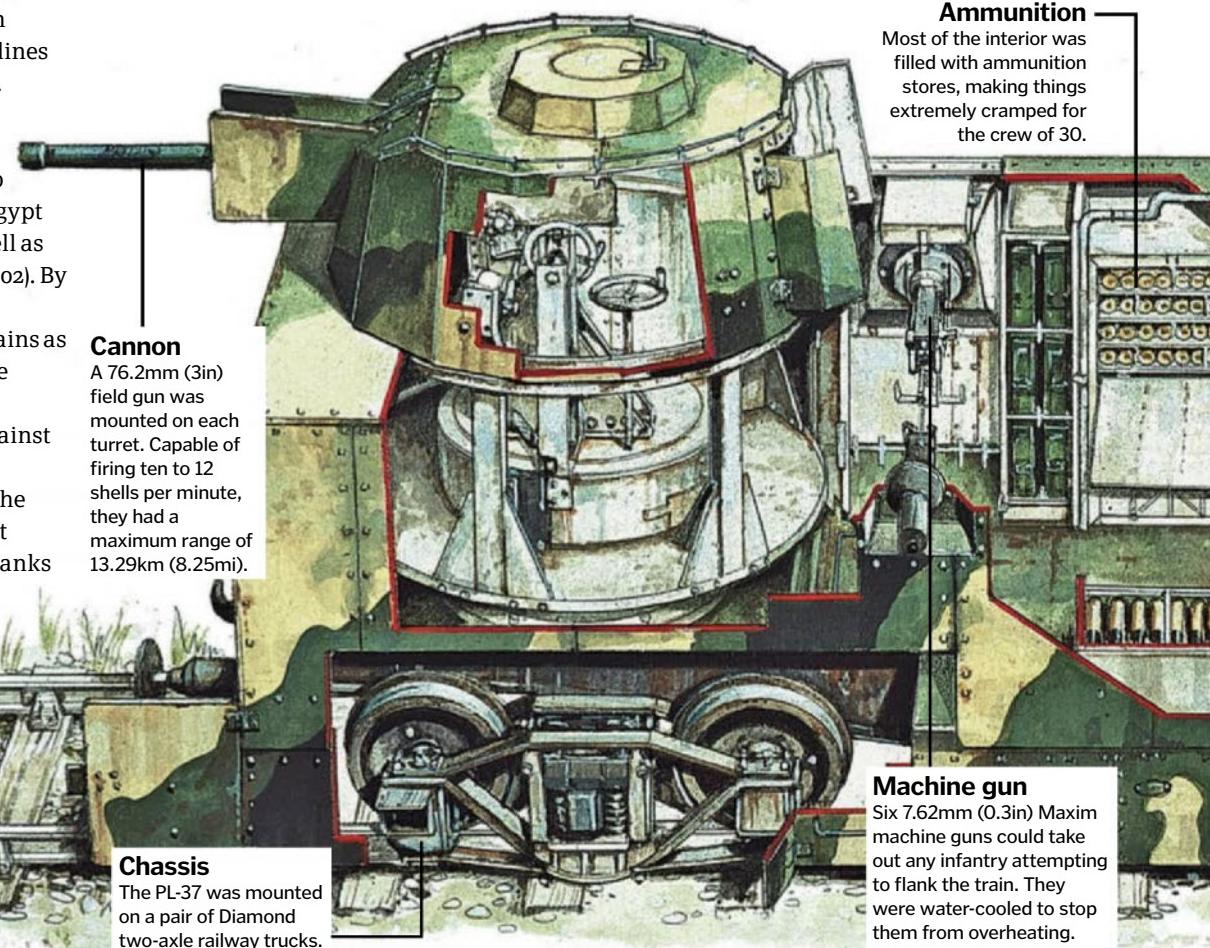
In June 1862, Confederate General Lee ordered that a cannon be mounted on a railway carriage, kick-starting the evolution of the armoured train as a means to not just protect the railway, but as an offensive weapon in itself, able to advance rapidly toward the lines and unleash a powerful artillery barrage.

It was over wide-open spaces where armoured trains really came into their own, and the British Empire used them to protect its far-flung interests, such as in Egypt (1882), Sudan (1885) and India (1886), as well as South Africa during the Boer War (1899-1902). By World War I (1914-1918), Britain and its continental neighbours saw armoured trains as best deployed against irregular forces like those they had faced in their colonial campaigns, and too vulnerable for use against professional armies.

Although a few models saw service on the Western Front, it was on the Eastern Front where armoured trains remained vital thanks to the poor infrastructure and vast distances of the Russian Empire. The Soviet Union inherited the previous regime's enthusiasm for rail-mounted combat and they were a feature of the Russian Civil War (1917-1920), the Polish-Soviet War (1919-1921) and the Eastern Front of World War II (1939-1945), where they saw service as both frontline artillery and anti-aircraft guns.



Soviet railwaymen work on an armoured train in the depot during WWII



# The railway warlord of China

When the Communists emerged victorious in the Russian Civil War, many defeated nationalist 'Whites' fled to China - and they brought their trains with them!

The vastness of China and the widespread nature of the fighting after the overthrow of the emperor in the Xinhai Revolution (1911) was ideal territory for armoured trains and they became most closely associated with

Manchurian warlord Zhang Zuolin.

As well as the 'White' trains and volunteers, including at least three generals and an entire cavalry regiment, Zhang employed Russian engineers to create similar armoured trains for his army. Fittingly, Zhang was assassinated in his train on 4 June 1928 when a bomb was planted on a railway bridge.



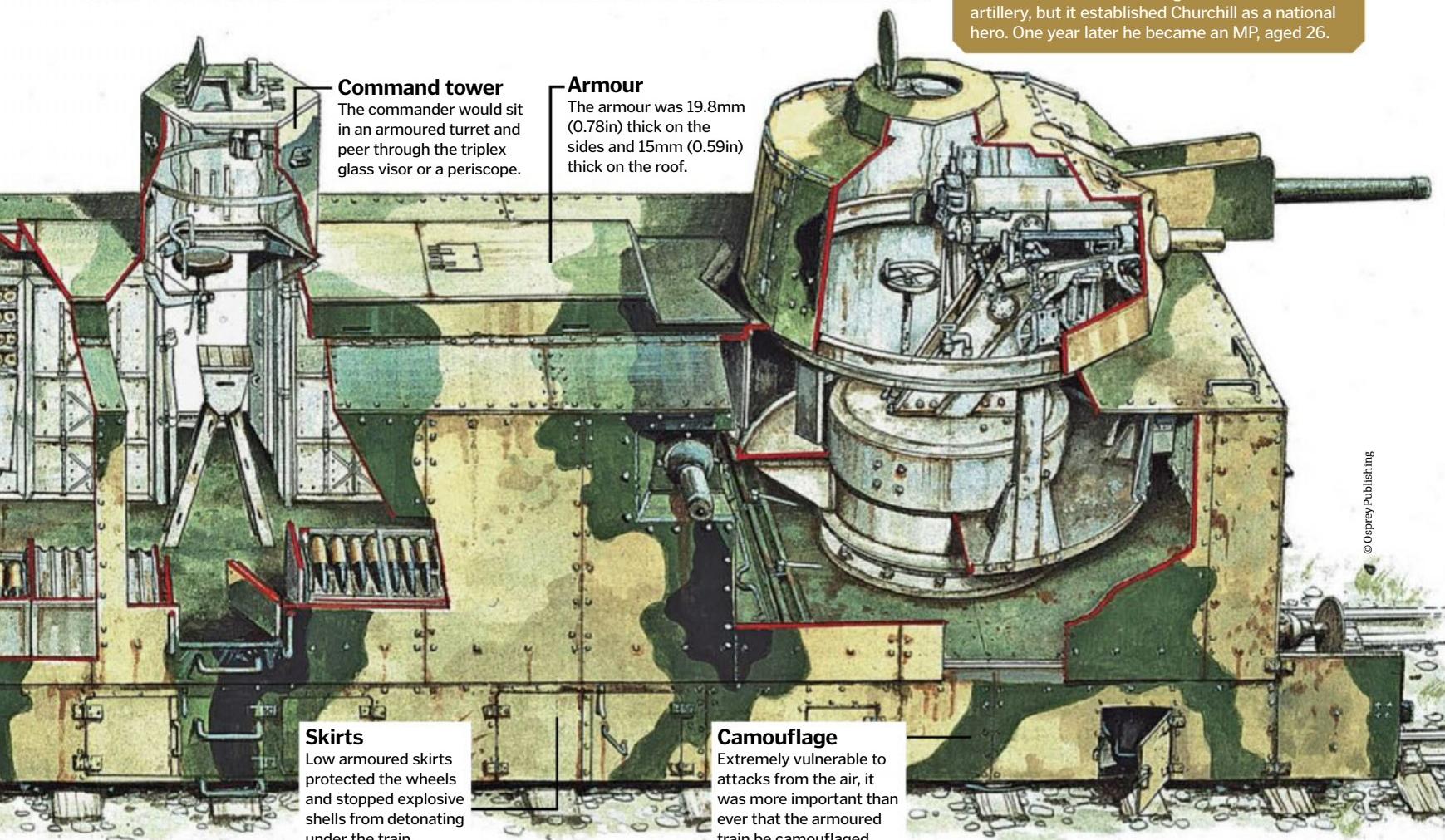
The wreckage of Zhang Zuolin's train after his assassination

Churchill in his military uniform, four years before his scrape in South Africa

## Winston Churchill's armoured train

Before he entered politics and then history, swashbuckling young cavalry officer-turned-war reporter Winston Churchill was captured along with 50 British soldiers when their armoured train was ambushed by a well-armed Boer militia in South Africa.

On 15 November 1899 they blocked the line with rocks and then opened fire with two field guns, taking out the train's naval gun. "The troops, who had maintained a hopeless fight with great courage, were overpowered," wrote *The Manchester Guardian* on 17 November. "Mr Churchill was last seen advancing with a rifle among the Dublin Fusiliers. He is believed to have surrendered himself to cover the retreat." This incident made it clear how vulnerable armoured trains were to organised foes with artillery, but it established Churchill as a national hero. One year later he became an MP, aged 26.





# FORENSIC SCIENCE UNCOVERED

REVEALED: THE INCREDIBLE TECH THAT SOLVES CRIMES AND CONVICTS CRIMINALS

**F**orensic science has never been under more scrutiny than right now. Since the dissolution of the UK's government-owned Forensic Science Service and the use of private contractors became the norm, every court in the country is on the lookout for mistakes and poor practice; the defence will try to discredit forensic experts to save their clients from prosecution.

The huge popularity of TV shows relating to forensics has not helped either. The general public's expectations have been raised; they expect 100 per cent accuracy and rapid results, both of which are misrepresented in many crime dramas. In some instances, this has led to miscarriages of justice, through the wrongful representation of various theories as undisputed fact. The public struggles to appreciate this; forensic science has long been thought of as a tool to expose wrongful convictions, rather than cause them. The popularity of forensics in the entertainment world has also aided criminals. They now tend to have greater awareness of many of the techniques used by forensic scientists, enabling them to avoid detection with greater success.

However, the technology used in forensics has developed hugely in the last century. Toxicologists no longer have to taste stomach contents to check for poisons, which was an unsavoury part of their job description during Victorian times. Instead, they can now use precise analytical techniques, such as mass spectrometry and high-performance liquid chromatography, to determine the exact quantity of compounds present in any test sample. DNA technology has breathed life into cases that have been left untouched for decades, and continues to be refined for greater accuracy.

Forensic technology has undeniably improved the police's ability to solve crime, but improvements are still needed. Experts are constantly trying to reduce the length of time analysis takes, as waiting weeks for a DNA result can have a detrimental effect on police investigations, allowing more time for criminals to evade detection. The amount of evidence that needs analysing has created a huge backlog, which means evidence has to be prioritised by what is most likely to reveal probative evidence.

It will be fascinating to see how forensic technology develops over the coming years and whether the new techniques we've featured speed up investigations and lead to convictions. ☀

## MATCHING GLASS TO SUSPECTS

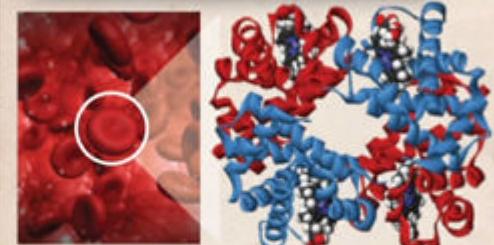
Using a clever type of mass spectrometry involving lasers, it is now possible for even the tiniest fragments of glass to be matched from an individual to crime-scene samples.



## DATING BLOOD SAMPLES

A revolutionary camera that can scan the visible spectrum of haemoglobin could make it possible to date blood stains to within a day, potentially even within an hour. This hyperspectral imaging device could enable police to immediately establish time of death, which currently takes days to achieve. It's thought that this technology could be adapted to confirm the presence of other fluids, such as saliva and sweat.

## HAEMOGLOBIN

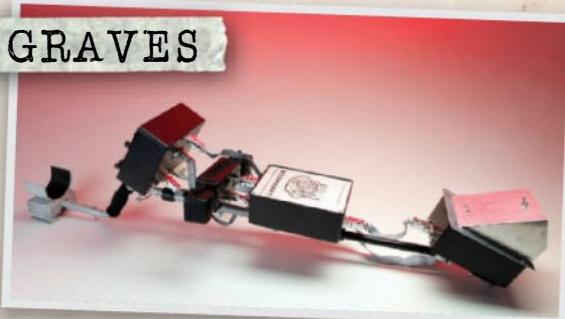


Haemoglobin is a protein made up of four polypeptide chains, each joined to an iron-containing haeme group

**DID YOU KNOW?** The roots of hairs can be used to determine gender, as they contain DNA

## SNIFFING OUT HIDDEN GRAVES

Locating hidden graves is both timely and costly, impacting law enforcement and military operations globally. The lightweight analyser for buried remains and decomposition odour recognition device – LABRADOR for short – claims to help find hidden graves. As our bodies decay, over 400 chemicals are released, producing a unique chemical signature that this device identifies. Its potential applications are vast, and include detecting narcotics, accelerants and even explosives.



## CRIME-SCENE PHOTOGRAPHY

When photographing a crime scene, it is imperative the photographer does not delete a single image, as this would be deemed as tampering with evidence.



## AREA OF CONVERGENCE

When bloodstain pattern analysts arrive at a crime scene, they will examine the distribution, size, shape and location of the bloodstains, to determine what has happened. Using the stringing method, the analyst will record the location of each spatter by employing the coordinate system. By determining both the angle and direction of each spatter, the starting point of the bloodshed and the victim's location are established.



## CRYSTAL PATTERN MAPPING

In order to make the identification of stolen goods harder, criminals will remove any form of serial number. By using electron backscatter diffraction (EBSD), it is possible to map the deformations in the metal's crystal structure, revealing the removed information. This technique could prove useful for reconstructing vehicle identification numbers, or even the imprints left on ammunition casings.

## Blood pattern analysis



### Cast-off

Cast-off stains are often formed when a bloodied weapon is swung through the air, casting blood onto a nearby surface.



### Shadowing or ghosting

A gap in an otherwise consistent spatter typically indicates that an object was present at the time of the incident.



### Swipes and wipes

Wipes are seen when blood on a surface is smeared, whereas swipes occur when an object covered in blood brushes a separate surface.



### Expiratory blood

Blood exhaled by a person creates a unique pattern. This is typically misty, somewhat resembling high-velocity spatter.



### Transfer

Transfer patterns form when a bloody object is pressed against a clean surface. This is often seen with bloody footprints.



# VIRTUAL AUTOPSY

CAN CAUSE OF DEATH BE ESTABLISHED WITHOUT DISSECTING A CORPSE?

Autopsies are a messy business in more ways than one. They can take hours to perform, and further analytical results can take months to produce. This not only delays forensic investigation; it can also add to the grief the deceased person's relatives experience. On top of this, researchers believe more than ten per cent of post-mortems are not completed to a satisfactory standard, meaning many suspicious deaths are never correctly identified.

The new virtual autopsy, or 'virtopsy', aims to speed up the entire process and achieve faster results. They offer the advantage of preserving a virtual form of the body, which can be continually reviewed and analysed. This will greatly increase accuracy, as multiple experts will be able to simultaneously examine the corpse, which is impossible to do during traditional post-mortems. The ability to gather nondestructive findings is a huge benefit of a 'virtopsy'; many families would rather their loved ones' bodies weren't subjected to the rigours of a traditional post-mortem. By using the virtopsy software, precise areas of interest can be chosen for further investigation, allowing pathologists to reduce the time they spend physically looking for clues in the body. Although unlikely to completely replace the traditional autopsy, the virtopsy has huge potential to speed up the process and greatly reduce the chance of missing vital evidence.

## VIRTOPSY TECH

**How is a virtual autopsy carried out, and what equipment is needed?**

### 3D scanning

By combining MRI and CT-scanning technology, it's possible to create a 3D scan of the body. This scan can be used to examine the body with more clarity than a standard autopsy.



### Heart-lung machine

During a virtual autopsy, this machine will circulate contrast solutions around the body, allowing clear visualisation of any circulatory problems that may have contributed to death.

## How traditional autopsies are performed



### 1 The Y-incision

The pathologist will perform a Y-shaped incision by cutting from each shoulder to the sternum, then down to the abdomen. This allows access to the major organs.



### 2 Organ removal

All of the body's major organs are removed and weighed for comparison. Blood and DNA samples are obtained and the heart is examined for signs of poisoning.



### 3 Stomach contents

The stomach contents reveal the deceased's last meal. Time of death can also be calculated by analysing the amount of digestion that has taken place.



**"The ability to gather nondestructive findings is a huge benefit of a virtopsy"**

**High-resolution surface scanner**

During an autopsy it's easy to miss a tiny fibre. This machine accurately scans the entire body, providing a detailed picture of what's on the skin's surface.

**Computer-supported biopsy**  
This machine works to choose the best tissue and fluid samples for analysis, which it can then help to analyse once they are collected.



**4 Brain examination**

The brain is thoroughly examined for signs of injury or abnormality. Often it will be preserved in formalin, which will harden the brain, allowing it to be dissected with greater accuracy.



**5 Replacement**

After all of the previous procedures have been conducted, the organs will be placed back inside the body cavity and the Y-incision will be sewed up. Samples may be further analysed.



## Roadside drug testing

Drugs have the ability to slow reactions, increase risk taking and alter judgement, all of which are detrimental to a person's ability to drive safely. It's important to remember that not only illegal drugs cause problems; people on prescription medication can be just as dangerous if they fail to follow their doctor's guidance.

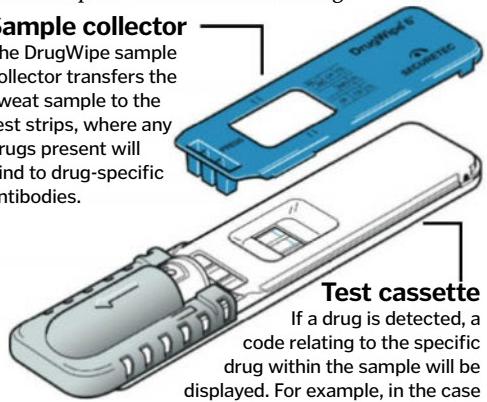
Drug driving is a frequent problem across the globe. Due to the overall lack of a definitive roadside test for drugs, many users believe they can get away with driving under the influence and tend to be more worried about being caught in possession. The UK and US have relied heavily on a set of impairment tests to detect drug intoxication, but these are unreliable and don't tell you the identity of the ingested drug.

The Securetec DrugWipe can detect up to five substances, including cocaine and cannabis, in a single test using a person's sweat. Results are available after three to ten minutes, making it feasible for police to use the device at the roadside. By using highly specific antibodies, it is able to guarantee reliable drug detection.

A range of other forms of DrugWipe are available depending on what you want to test for. This includes a test for ketamine, which is currently the fourth most popular recreational drug in the UK. Using sweat is a more reliable test of impairment compared to many oral tests. This is because drug deposits can form in the mouth, providing a positive test even though the drug may have been taken days before, meaning the individual would not be impaired at the time of testing.

**Sample collector**

The DrugWipe sample collector transfers the sweat sample to the test strips, where any drugs present will bind to drug-specific antibodies.



**Test cassette**

If a drug is detected, a code relating to the specific drug within the sample will be displayed. For example, in the case of cannabis, "CA" would be shown.

© Thinkstock



# FORENSIC HOLODECK RECREATES CRIMES IN 3D

NEW VR TECH WILL HELP JURY MEMBERS VISUALISE CRIME SCENES

Reconstructing a crime scene is one of the toughest jobs for any forensic scientist. This is particularly apparent when they give evidence in court. It's vital that both the judge and jury are able to develop detailed knowledge of any crime scene, in order to figure out what happened as well as the precise order of events. Without live footage of the scene, this has been incredibly difficult to achieve; photos of the scene and other types of evidence presented to the jury often leave much to the imagination.

By combining MRI, CT, laser-scanning technology, camera footage, eyewitness statements and the virtual reality headset, Oculus Rift, the forensic holodeck has been created. Using this new technology, all members of a courtroom may soon be able to walk through the crime scene in high-resolution 3D. Named after the simulated-reality device featured in *Star Trek*, an advantage of the forensic holodeck is that it can simplify a scene. This can help show exactly the evidence in question, or make particularly violent scenes less traumatic for the jury. Being able to appreciate a particular individual's line of sight is another significant benefit, as this can show whether someone is telling the truth about what they saw, or whether a suspect could be seen by certain individuals.

The Oculus Rift is able to measure the user's orientation in real-time, which allows crime scenes to be viewed with the correct perspective. Originally designed for use in the world of videogames, the Oculus Rift has been modified so that it can measure the user's position with the help of an optical tracker.



Multiple perspectives  
Moving around the scene enables the user to appreciate the different perspectives of the people involved, which may help to explain why their accounts of the events differ.

## How lies can be 'seen' in the brain

Researchers claim to have found the gold standard in lie detection, by monitoring the brain with functional magnetic resonance imaging (fMRI). Research has shown that telling lies increases blood flow to the brain, which in turn increases oxygen levels. This increased oxygen level causes the brain to brighten in the fMRI image. Scientists believe this method is much harder to cheat than a traditional polygraph, as the fMRI continually tracks changes in the brain. Polygraphs only measure typical stress responses and link them to the chance of a subject answering untruthfully.



## Polygraphs debunked

Polygraphs detect lies by measuring physiological changes, such as blood pressure and sweating. The key to beating them is to answer the control questions strangely. Your control answers are what the polygraph bases your test answers on, therefore by changing your blood pressure, respiratory rate and sweat levels when telling the truth, the polygraph won't be able to detect lies during the test.



Polygraph tests aren't standardised and therefore they lack scientific validity

### Bullet trajectories

The red and yellow line shows clearly the bullet's trajectory, revealing how close certain people were to being shot.



**Victim location**  
By moving around the scene, it's possible to appreciate the exact locations of the various suspects, victims and witnesses.



**"Telling lies increases blood flow to the brain"**

## DIY spiking test

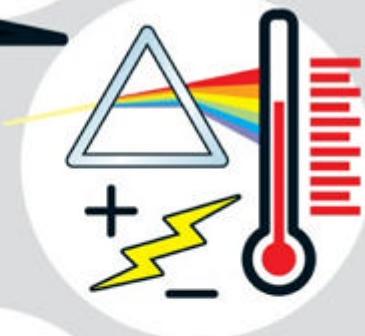
How to perform your own forensic analysis to see if your drink has been spiked

Proving someone has had their drink spiked is notoriously hard to do. For many years, claims of being spiked have been met with scepticism, and any symptoms reported by the individual put down to alcohol intoxication. The problem lies in the fact that very little evidence is ever preserved; the drug is often completely metabolised by the time the victim reports the crime and the glass has usually been cleaned or lost.

Similar in shape and size to a USB stick, the Personal Drink Identification Device, or pd.id, aims to let users test their own drink to see whether it contains a common date-rape drug. Operated simply by dipping it into a drink, it can identify whether your drink has been modified in some way, by examining the drink's components. It then compares them to a preloaded database of known substances and drink characteristics, to see whether or not there are any anomalies present in the drink.



Once the pd.id is submerged in the drink, it collects a small sample of liquid in a reservoir.



By performing three tests involving light, current and temperature, the drink's components are analysed.



The analysis takes only a few seconds; once it's complete the LED light will indicate whether the drink is safe to consume.



By linking with your smartphone, the pd.id can access a larger database of drink profiles, and can text or call you if your drink is contaminated.



# What are buoys for?

Learn how these simple floating devices keep sailors safe and provide valuable scientific information

**B**uoys serve a number of important purposes in our waters. They were first documented in 13th-century Spain, where they were used to help ships navigate into the port of Seville. The word 'buoy' is thought to have derived from the Middle Dutch word 'boeye', meaning 'float.' By definition, they are a float that is usually anchored, often made of plastic or fibreglass.

Part of their function is to alert people at sea to potential hazards, such as rocks or dangerously shallow water. In areas where many ships operate, buoys can be used to indicate the location of shipping lanes, reducing the risk of collisions between boats. The majority of small buoys found in harbours will act as mooring devices, allowing boats to be anchored in place without needing to be attached to a dock.

Buoys are also hugely significant for science. They are used throughout the world to collect data on ocean currents, climate change and the weather. Many weather forecasts use buoys to predict weather patterns and learn more about the conditions in specific regions.



Large marker buoys can function to show the location of deep channels, providing safe passage for large merchant vessels

# Turn ashes into diamonds

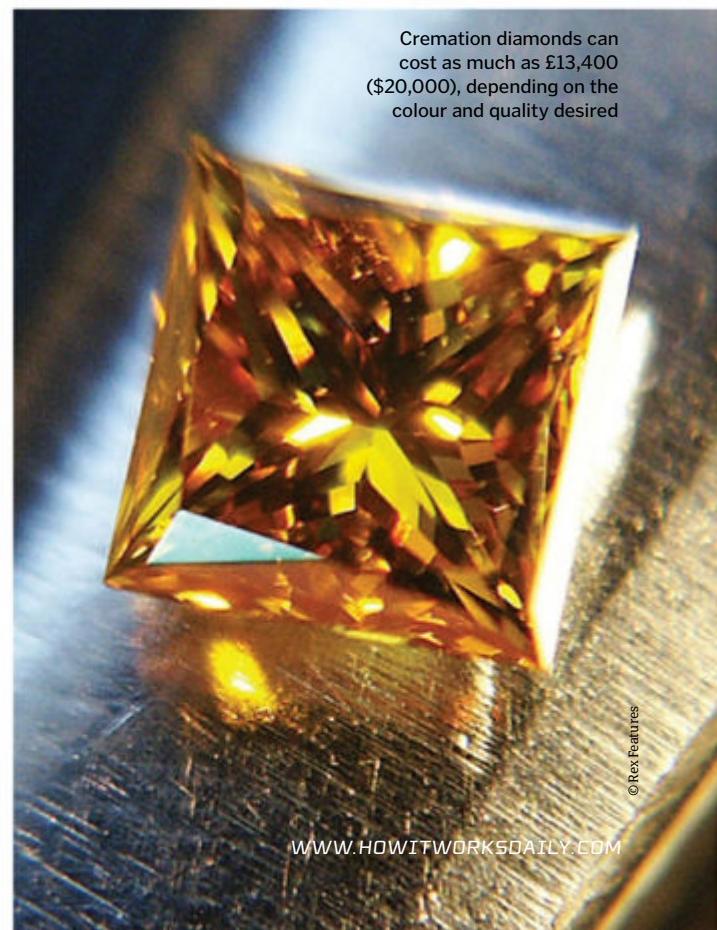
How high temperatures and pressures can convert our bodily carbon into cremation diamonds

**K**nowing how to commemorate a loved one's passing is incredibly difficult for us all, but there is now a wide range of alternatives to traditional burial or cremation. An alternative to sending your relatives' ashes into orbit, a technique has been devised to convert them into diamonds. A typical 80-kilogram (176-pound) man produces enough ashes to make a 0.2-gram (0.007-ounce) diamond, as our bodies are 18 per cent carbon.

To do this, the ashes are heated to over 2,760 degrees Celsius (5,000 degrees Fahrenheit) in a heat-proof crucible. This works to oxidise all of the elements within

the ashes, other than the carbon. The carbon is then heated for a number of weeks to turn it into graphite, which is then pressed with a metal catalyst and a diamond-seed crystal. This step requires temperatures of around 1,371 degrees Celsius (2,500 degrees Fahrenheit), along with extremely high pressures, and needs several weeks to convert the graphite into a rough crystal. This crystal can then be cut to specification and presented as desired. The finished diamond's colour is typically yellow or orange, depending on the amount of other trace elements within the original ashes. This can be changed by further enhancement techniques.

Cremation diamonds can cost as much as £13,400 (\$20,000), depending on the colour and quality desired



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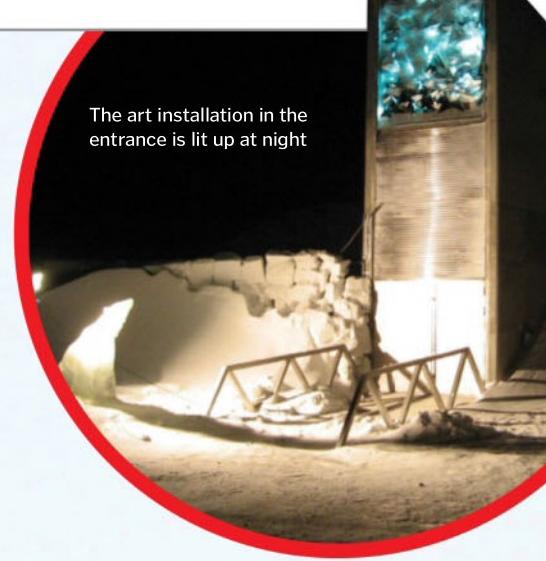
# The Doomsday Seed Vault

## Welcome to the Swiss bank of the agricultural world

Deep within the Arctic Circle, on the frozen island of Spitsbergen in the Norwegian Svalbard archipelago, is a giant vault. It's something you'd half expect to find in a Bond movie: set 120 metres (394 feet) inside a mountain, it's the site of an old coal mine and boasts some formidable security features that include reinforced concrete walls, dual blast-proof doors, motion sensors and airlocks. The island's remote location, just 1,300 kilometres (808 miles) from the North Pole, its inhospitable climate and treacherous terrain make monitoring human activity in the area relatively easy. The 1,750 banks from around the world, which have made hundreds of thousands of deposits to this vault, can sleep easy knowing their investments are secure. But this is no safe house for cash or gold, or a financial institution of any kind.

The Svalbard Global Seed Vault is a giant repository for the world's seed crops, an effort on the part of several multinational corporations and governments to protect future crop diversity. This includes the Bill and Melinda Gates Foundation along with a conglomerate of corporations with agricultural interests known as the Global Crop Diversity Trust, and the Ministry of Agriculture and Food on behalf of the Norwegian government.

Svalbard is an ideal choice for the vault's location as a kind of fail-safe, should worldwide seed banks fail. It's remote, but has good infrastructure and a ready supply of coal to power the facility. The sandstone the vault is set into is low in radiation and stable, plus it's very cold, so the rooms will remain cold even if the refrigeration units fail.



The art installation in the entrance is lit up at night



The entrance is the only part of the Svalbard Global Seed Vault that stands above ground

### How does it protect our food?

Last year, around 10,000 new varieties of food crop seeds were added to the Svalbard Global Seed Vault from over 100 countries all over the world, bringing the total number of seed samples contained within the vault to over 835,000. But if these are being already grown in the countries they're native to, what's the point in a worldwide seed vault? In the event of natural disaster or civil war destroying crops, the seed vault provides a back-up for the seed banks in that country

- and we've already seen it prove its worth as a contingency: the Philippines national seed bank was damaged by flooding and then fire, while Afghan and Iraqi banks have been wiped out by wars in those regions. Anyone who wants access to the seeds, such as plant breeders or researchers, must go through the seed bank that made the deposit: even though the vault is managed by the Norwegian government, the depositors retain sole ownership of the seeds.

Heat-sealed, four-ply aluminium bags are used to store and preserve each seed sample



**DID YOU KNOW?** In 2005, a 2,000-year-old Judean date palm seed from Herod's palace in Israel was grown into a plant

## The world's coldest bank

In the event of the unthinkable, the Svalbard Global Seed Vault can preserve our food crop history

**Deep inside the mountain**  
It's 145.9m (478.7ft) from the entrance to the back of the vault.

**Natural protection**  
The vault is set deep into the sandstone of the mountain of Plataberget.

**Vault rooms**  
The three rooms inside the vault are around 10m (33ft) wide, 6m (20ft) high and 27m (89ft) long each.

**Seed storage**  
The Svalbard Global Seed Vault can hold up to 4.5 million seed samples, for a maximum 2.25 billion individual seeds.

**Control room**  
Here, the temperature of the vault is maintained and the facility is monitored.

**Refrigeration units**  
Compressors cool the already frigid air down to a constant -18°C (-0.4°F).

**Seed stacking**  
Dozens of shelves in each room hold hundreds of boxes, containing hundreds of packets, containing around 500 seeds each.

**A work of art**  
Crowning the roof and entrance of the facility is an illuminated artwork made of mirrors, prisms and 200 fibre-optic cables.



## Preserving our food future

Duplicate samples of seeds from national seed banks are stored in sealed aluminium bags that exclude moisture, then shelved in itemised containers, the contents of which are recorded and held on a database maintained by the Norwegian authorities. The bedrock that surrounds the vault is a temperature of minus-three degrees Celsius (27 degrees Fahrenheit), although the facility is kept even colder by refrigeration units that chill the seeds to minus-18 degrees Celsius (minus-0.4 degrees Fahrenheit). The island of Spitsbergen is tectonically inactive and even if the ice caps melted, the site lies high enough to remain above sea level. Under these conditions, seeds will remain viable for hundreds or even thousands of years.





# The truth about

Everything you need to know about this sweetener, from how it's made to where it's hiding

**S**ugar is an important – and popular – part of our daily diet.

Along with starch, it falls within the carbohydrate group as it consists of carbon, hydrogen and oxygen atoms and acts as fuel for the body. In fact, carbohydrates are our main source of energy, converted by the body to power our cells and keep us alive and growing.

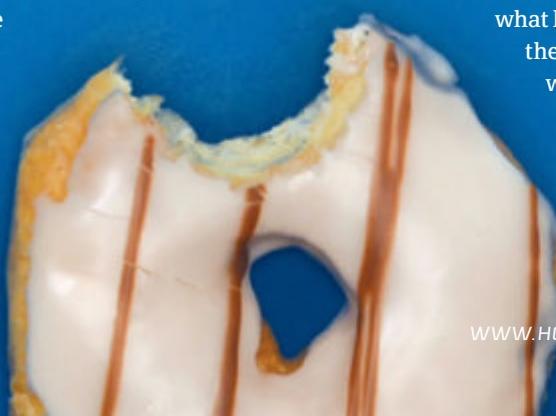
However, many of us are overindulging in the white stuff, with the average adult consuming approximately 63 grams (2.2 ounces), nearly 16 teaspoons, of sugar each day. That's over twice the recommended daily intake. The main attraction to sugar, for both humans and animals, is its sweet taste. In nature, this is a useful indication of which foods are safe to eat, as poisonous fruits and plants tend to be sour or bitter, but in the

modern world of processed foods and fizzy drinks, sweetness is mainly associated with pleasure. As a result, sugar is added to many of the foods we consume each day to artificially boost the flavour or texture, or act as a preservative by hindering the growth of bacteria. This may be good news for our taste buds, but it's not so good for our health.

By eating more sugar than our bodies actually need, we are storing the excess as fat, leading to an increase in obesity and many other health problems throughout the world. Keeping track of how much

sugar we eat can be difficult, though, as it goes by many different names and is hidden in some unlikely foods. Plus, not all sugars are bad, but working out which ones are good can be a challenge.

Over the next few pages, we will reveal the facts about sugar you need to know. Find out where it comes from and how it is processed, and discover exactly what happens when it enters the body. We also reveal whether you can really be addicted to sugar, and examine just how much of it can actually be found hiding in so-called 'healthy' foods. \*



# Where sugar comes from

The white stuff we know as sugar is sucrose, a carbohydrate made up of two other sugar molecules, glucose and fructose, linked together. Sucrose is present in most plants, but the highest concentrations can be found in sugarcane and sugar beets, which is why these crops are the main source of commercial sugar production across the world. Sugarcane was the original sugar plant and is now the source for 75 per cent of the world's sugar needs. Sugar beet was originally grown as a garden vegetable, until its sugar content was realised around 1747. Today, it makes up the remaining 25 per cent of the world's sugar supply.

*"The average adult consumes approximately 63 grams, nearly 16 teaspoons, of sugar each day"*

## Towering canes

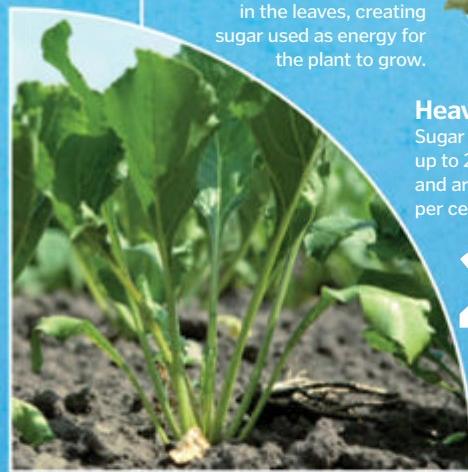
Sugarcane stalks can grow up to 7m (23ft) tall and bare small flowers when they mature.



**75%**  
Sugarcane

## Leaves

Photosynthesis takes place in the leaves, creating sugar used as energy for the plant to grow.



## Heavy roots

Sugar beet roots can grow up to 2kg (4.4lb) in weight and are approximately 16 per cent sugar.

**25%**  
Sugar beet

## Harvesting

When harvested, the stalks are chopped off, but the roots are left so the plant can grow again.

## One eighth sugar

Approximately 12 per cent of the weight of harvested sugarcane is sugar.



## Unrefined sugars

White sugar is refined before it hits the shelves but these sweet treats are all natural

White sugar and many types of brown sugar are refined before they hit the supermarket shelves. During the refining process, minerals and nutrients including calcium, iron and potassium are stripped away, and chemicals such as phosphoric acid, sulphur dioxide and formic acid are added. Therefore, refined sugar is considered empty calories, providing energy, flavour and not much else. Unrefined sugars have a higher nutritional value. They are naturally brown in colour, so can be easily confused with refined brown sugars, which are artificially coloured by adding extra molasses that are otherwise removed during the refining process. There are several sources of raw sugar that can satisfy your sweet tooth, including fruit and these tasty natural substances...



## Maple syrup

- Maple syrup is produced from the sap of maple trees in Canada and the United States
- The trees contain starch, which is turned into sugar by enzymes each spring
- The thin watery sap is extracted from the tree and boiled to make syrup



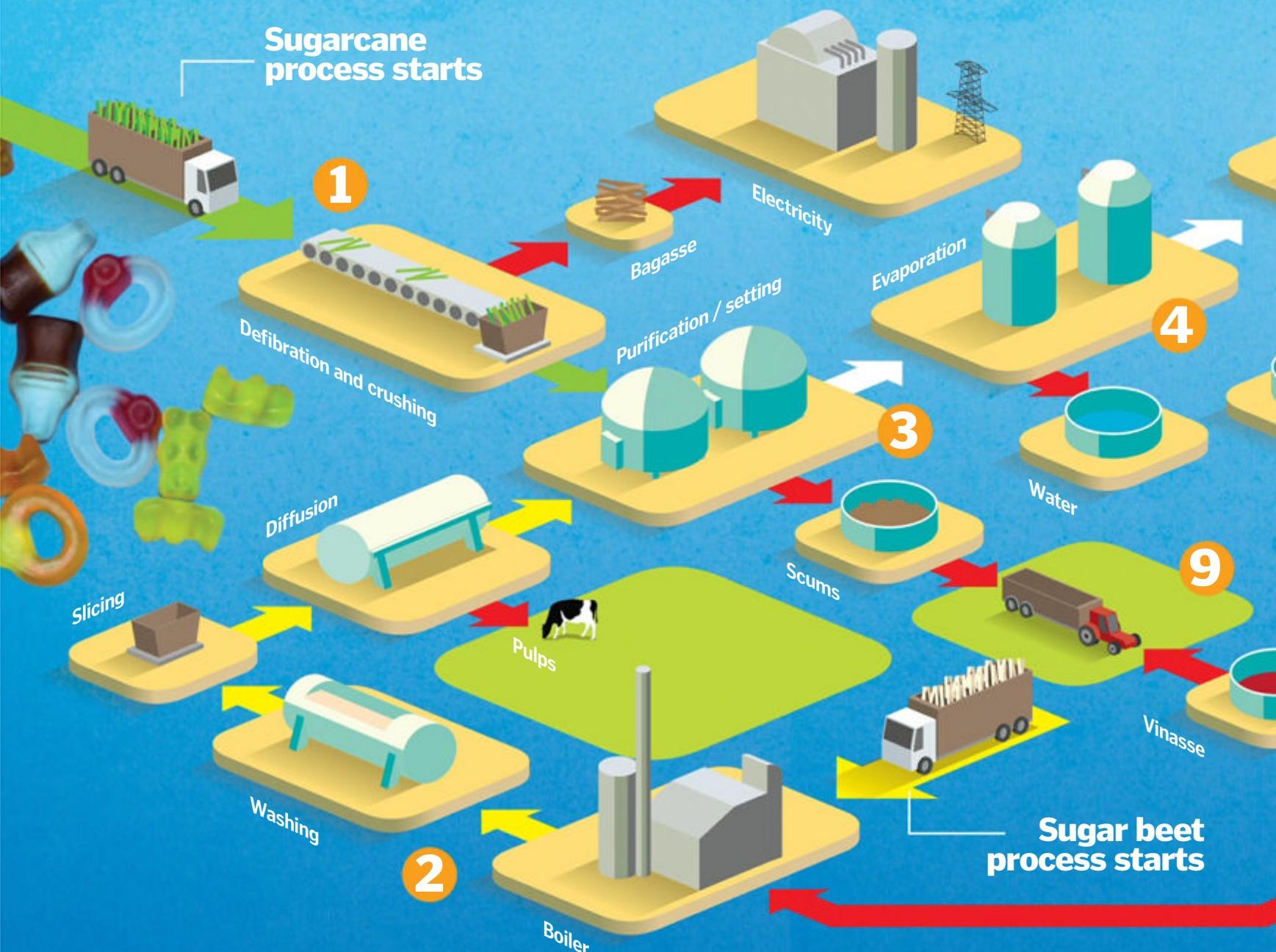
## Molasses

- Molasses, or black treacle, comes from sugarcane and sugar beets, and it occurs as a by-product of the refining process
- It contains the vitamins and minerals present in the original plant, and has some sugar content
- Molasses is used to make rum and is what gives gingerbread its rich taste



## Honey

- Bees extract nectar from flowers and digest it to change its chemical composition
- Once deposited into a honeycomb, bees fan the watery honey with their wings to evaporate the water
- The bees then seal the honeycomb by secreting a liquid from their abdomen that hardens into beeswax



# Inside a sugar factory

How plants are turned into little white crystals of sugar

Whether it's produced from sugarcane or sugar beets, white refined sugar is 99.9 per cent sucrose. However, although the end product is the same, the method of production differs depending on the source. Sugar from sugarcane is extracted close to where it is grown, so the plant doesn't have time to rot after

harvesting. It can then be shipped elsewhere for processing. Sugar beets can be stored for longer, so the sugar is typically extracted and processed away from where the crop is harvested. It's not just sugar that is produced from these crops, though, as by-products including alcohol, fertiliser and even electricity are made too.



## 01 Sugarcane

The sugarcane stalks are crushed between rollers to separate the juice, which contains the sugar, and fibrous material known as bagasse. The bagasse can then be recycled as paper or fuel to further power the factory.

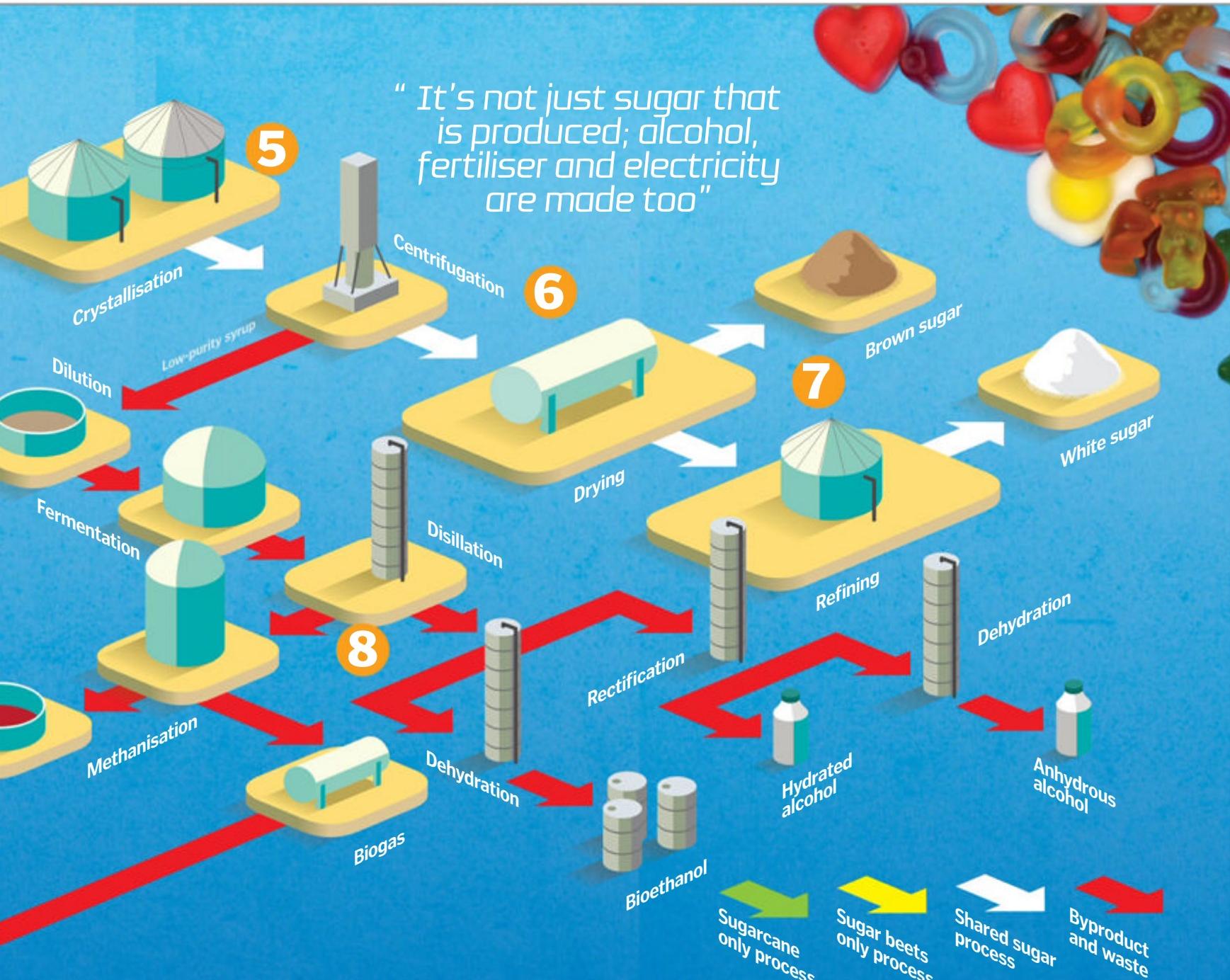
## 02 Sugar beets

The roots of the sugar beets are washed and cut into strips, and then run through hot water to extract the sugar. The remaining pulp is used as animal feed, while the sugary solution moves to the next stage.

## 03 Purification

Milk of lime is added to the sugary solution, or juice, to neutralise its natural acidity. It is then heated to boiling point to remove any impurities, leaving behind a sludge that can be used as fertiliser.

**DID YOU KNOW?** One hectare (2.5 acres) of sugar beet crops can produce seven tons of sugar.



## 04 Evaporation

To concentrate the clear sugary juice, two thirds of its water content is removed through vacuum evaporation. Steam causes the mixture to boil, creating a syrup, which is 65 per cent sugar, and vapour that is then condensed into water.

## 05 Crystallisation

**5** The syrup is boiled again until it becomes saturated with sugar. Small grains of sugar are then added to act as nuclei for the sugar crystals to form around. This process continues until the crystals reach the required size.

## 06 Centrifugation

The mixture is spun.

The mixture is spun at high speeds in perforated drums, similar to washing machines. The syrup, or molasses, is thrown off and removed via perforations, leaving damp sugar crystals that are dried by being tumbled through heated air.

# 07 Refining The raw sugar

**Step 5** The raw sugar is washed, dissolved, clarified and filtered to remove more molasses and impurities, to make white sugar syrup. Steps 4 to 6 will repeat until white granulated sugar is produced, ready to be packaged and shipped.

## 08 Alcohol The molasses

The molasses are diluted, fermented and distilled with yeast to make alcohol. This turns into high-purity alcohol, dehydrated alcohol or bioethanol, a biofuel that makes environmentally friendly energy.

## 09 Fertiliser A by-product

**5** A by-product of alcohol production is vinasse. Its high potassium content makes it a great farming fertiliser, and it is also a source of methane, which can be turned into biogas for generating heat or electricity.

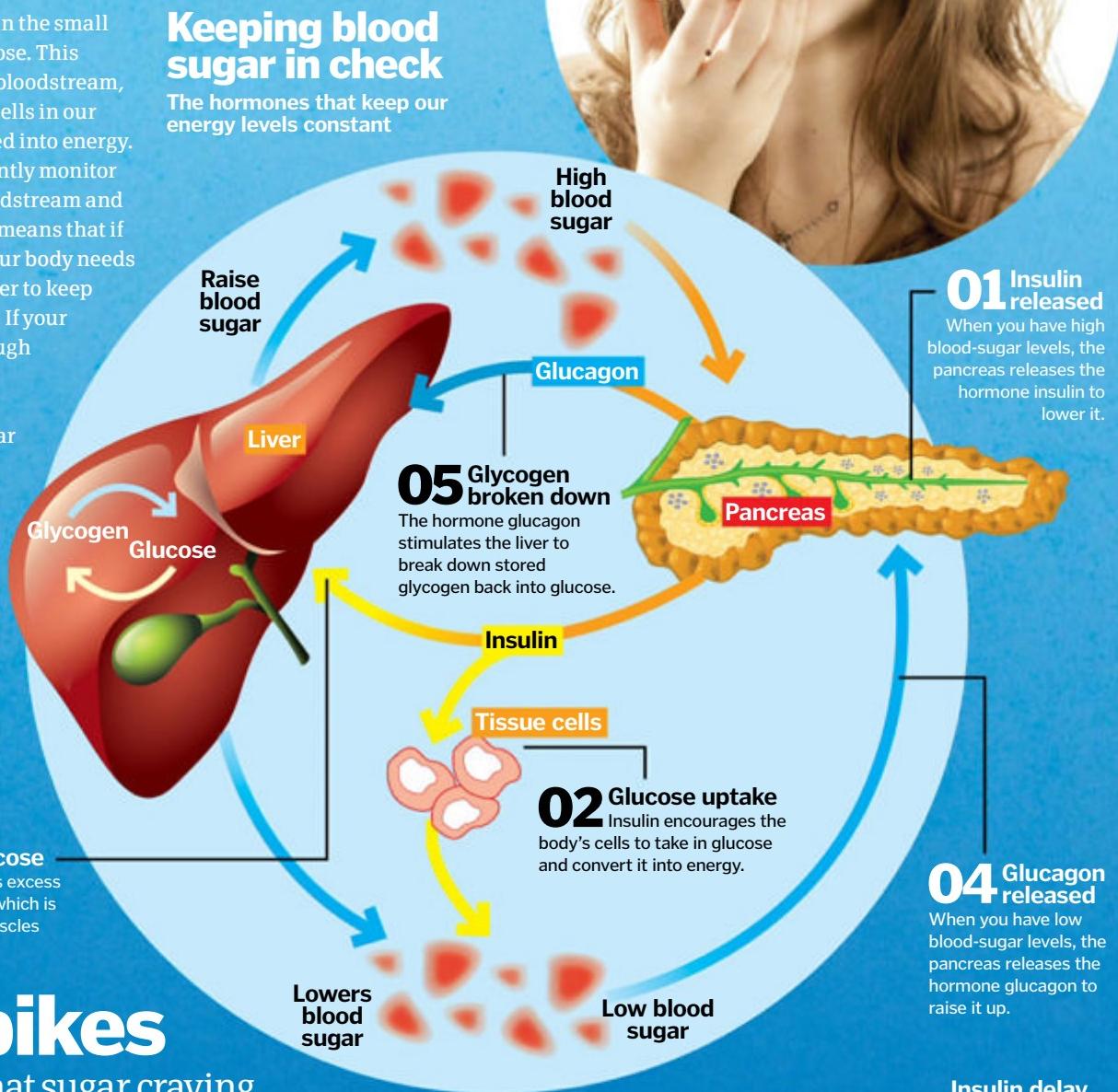


# Sugar in the body

How we use sugar for energy and regulate its levels

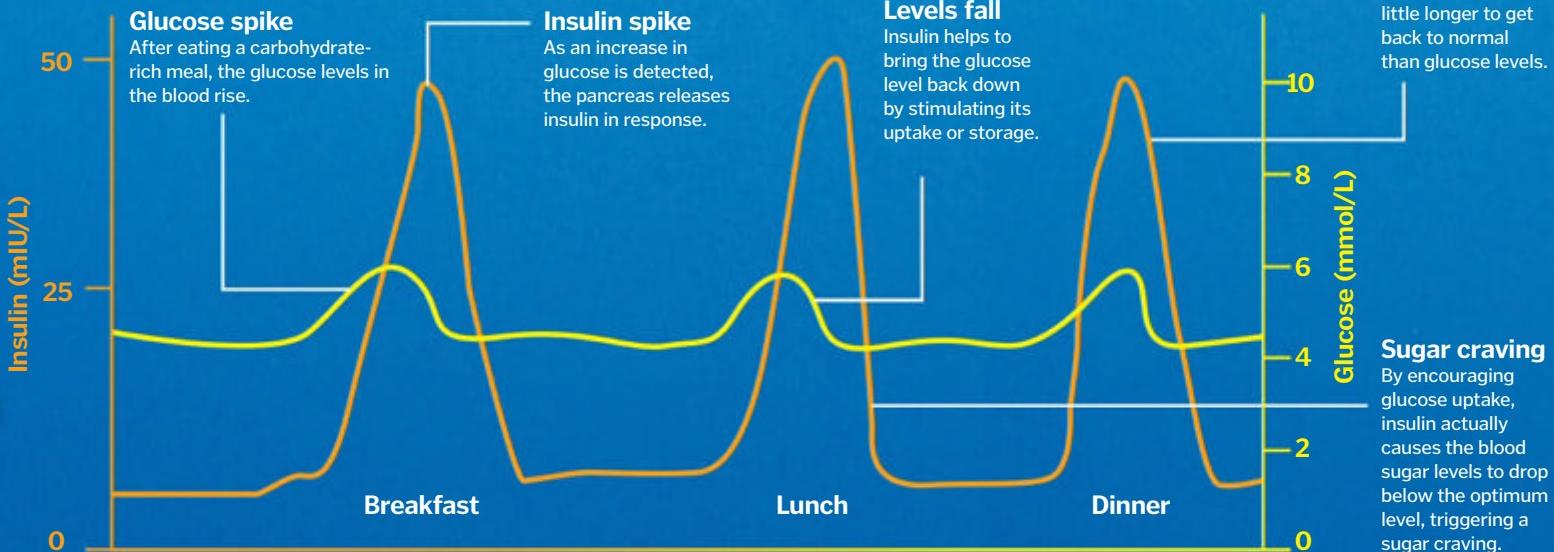
When we digest sugar, enzymes in the small intestine break it down into glucose. This glucose is then released into the bloodstream, where it is transported to tissue cells in our muscles and organs and converted into energy. Beta cells in the pancreas constantly monitor the amount of glucose in the bloodstream and release insulin to control it. This means that if you consume more sugar than your body needs right away, it can be stored for later to keep your blood-sugar levels constant. If your body stops producing any or enough insulin, or if your cells become resistant to it, this can result in diabetes, leaving your blood-sugar levels to rise to dangerous levels.

**"Beta cells in the pancreas constantly monitor the amount of glucose in the bloodstream"**



## Sugar spikes

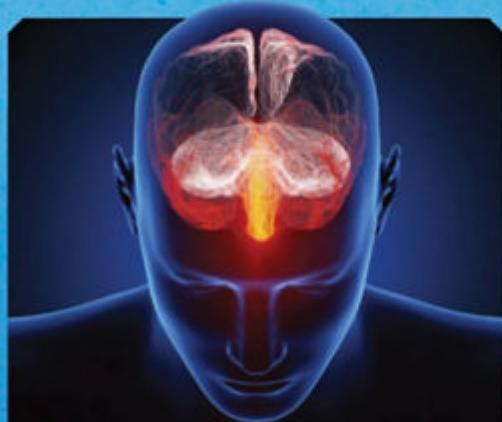
The reason we get that sugar craving



# Too much sugar

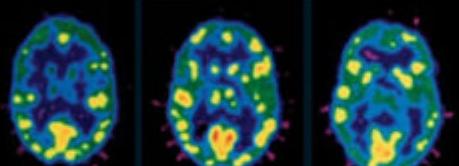
What happens to your body when you overindulge your sweet tooth?

Sugar is essential for the human body as it powers the cells that keep us alive. However, eating too much of it can also have a negative effect on our health. Foods with added sugar that does not occur naturally contain empty calories, meaning that they have no other benefit than to provide energy. If we eat more sugar than our energy levels require, then our bodies have to find something else to do with it, creating a whole host of problems. Excessive sugar consumption is one of the leading causes of obesity, heart disease and diabetes.



## Sugar on the brain

As humans, we are programmed to love sugar. Our primate ancestors evolved to seek out sweet foods for their high-energy content to increase their chance of survival when food was scarce. Nowadays food is much more readily available, yet we still can't get enough of the sweet stuff. The reason for this is all in the brain. When we eat sugar, the brain releases dopamine and serotonin, the hormones that boost your mood, which then stimulate the nucleus accumbens – the area of the brain associated with reward. This is a similar process that leads to drug addiction, which is why we get those sugar cravings. Regular sugar consumption can also inhibit dopamine transporters, which can lead to you needing to eat even more sugar to get the same pleasure reward as before. In addition, fructose, which is used to sweeten many foods and drinks, doesn't suppress hunger hormones like glucose does, meaning your body is unable to tell when you've eaten enough.



Sugar is addictive, triggering a similar reward process in the brain to cocaine or heroin

## Where does it go?

The effects sugar can have on your health

### Tooth decay

Some of the sugars we eat stick to our teeth and attract bacteria. The bacteria feed on these sugars and produce lactic acid that wears down the tooth enamel.

### Diabetes

High blood-sugar levels can cause the body to produce excess insulin, which can damage the pancreas and leave the body resistant to it.

### Liver disease

Fructose, a component of sucrose, can only be converted to energy by the liver. Any excess is converted into liver fat, which can lead to liver disease.

### Suppressed immune system

Processing sugars that are void of nutrients requires nutrients from elsewhere in the body, depleting your supply of vitamins and minerals.

### Heart disease

Sugar increases triglyceride levels, the fat levels in the blood, which can increase the risk of heart disease.

### Obesity

Excess sugar that isn't converted into energy ends up being stored as fat in the body. This can lead to further health problems.



## Sweet surprises

How much sugar are you eating without even knowing?

**0.5tsp**

White bread  
1 slice



**1tsp**

Salad dressing  
100ml serving



**7.5tsp**

Fruit smoothie  
250ml serving



**2tsp**

Cereal bar  
1 bar



**5tsp**

Dried fruit  
30g serving



**2tsp**

Cereal  
100g serving



Cereal  
100g serving

**1tsp**

Tomato ketchup  
15ml serving



**11tsp**

Flavoured coffee  
340ml serving

**1.25tsp**

BBQ crisps  
100g serving



**1tsp**

Low-fat ready meal  
400g serving

**0.75tsp**

Plain croissant  
1 croissant



"Sugar comes in many forms but they typically have names ending in -ose"

# Where is sugar hiding?

The shocking amounts of sugar found in unexpected places

The high sugar content of foods such as sweets, chocolate, cakes and fizzy drinks is well known, but some foods we generally consider as 'healthy' and not particularly sweet also have a surprising amount of sugar in them.

Sugar comes in many forms but they typically have names ending in -ose. As well as glucose and fructose naturally found in fruit, vegetables and honey, lactose and galactose can be found in milk and dairy products, and maltose in barley. These natural sugars are fine in moderation as they also come with other nutritional benefits. For example,

a piece of fruit will also contain fibre, which helps limit the amount of fructose the body absorbs.

Added sugar, used to improve the taste and textures of foods and drinks, is the type that is considered unhealthy. This usually comes in the form of sucrose, or as a sugar substitute such as sucralose, saccharin, aspartame or high-fructose corn syrup (HFCS). HFCS is artificially produced from corn and used in many processed foods and fizzy drinks. To find out how much sugar is in your food, check the 'carbohydrates - of which sugars' value on the label.



## SUGAR STATS

WHICH AREAS CONSUME THE MOST SUGAR?



YOU WOULD NEED TO WALK BRISKLY FOR 30 MINUTES TO BURN THAT OFF

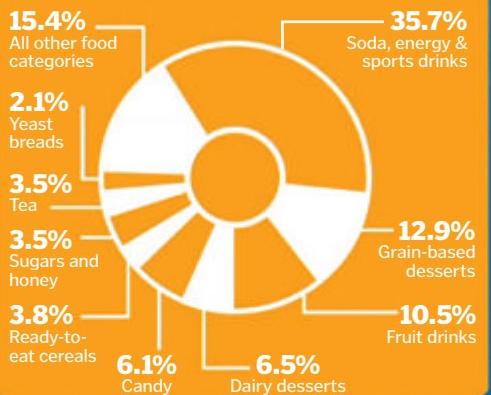


**25 GRAMS** RECOMMENDED DAILY SUGAR INTAKE FOR THE AVERAGE ADULT

THE AVERAGE AMERICAN CONSUMES 22 TEASPOONS OF SUGAR EACH DAY = 9 GLAZED DOUGHNUTS



## ADDED SUGAR IN THE AMERICAN DIET



# How do Bunsen burners work?

Find out how its flame reaches temperatures of up to 1,200°C

**R**obert Bunsen invented the Bunsen burner in the mid-19th century as a means to an end. The German chemist's work focused on emission spectra, which is the bright light produced by different elements when they are heated in a flame. To carry out this experiment he required a hot, clean flame, which gave him the idea for the Bunsen burner. A modern Bunsen burner consists of a straight metal tube, measuring about 13 centimetres (five inches) long, attached to a base stand. A thin rubber tube known as a gas hose connects to the bottom and supplies gas to the Bunsen. The metal collar works to adjust the amount of air that enters the tube by altering the size of the air hole at the base. By allowing air and therefore oxygen to mix with the gas, a hotter and more complete reaction occurs, causing a very hot, blue flame to be produced. The Bunsen still has an abundance of laboratory applications today, including sterilisation and fixing cells to microscope slides. ☀



Bunsens are typically fuelled with natural gas, which is almost pure methane, CH<sub>4</sub>

## The physics of foam

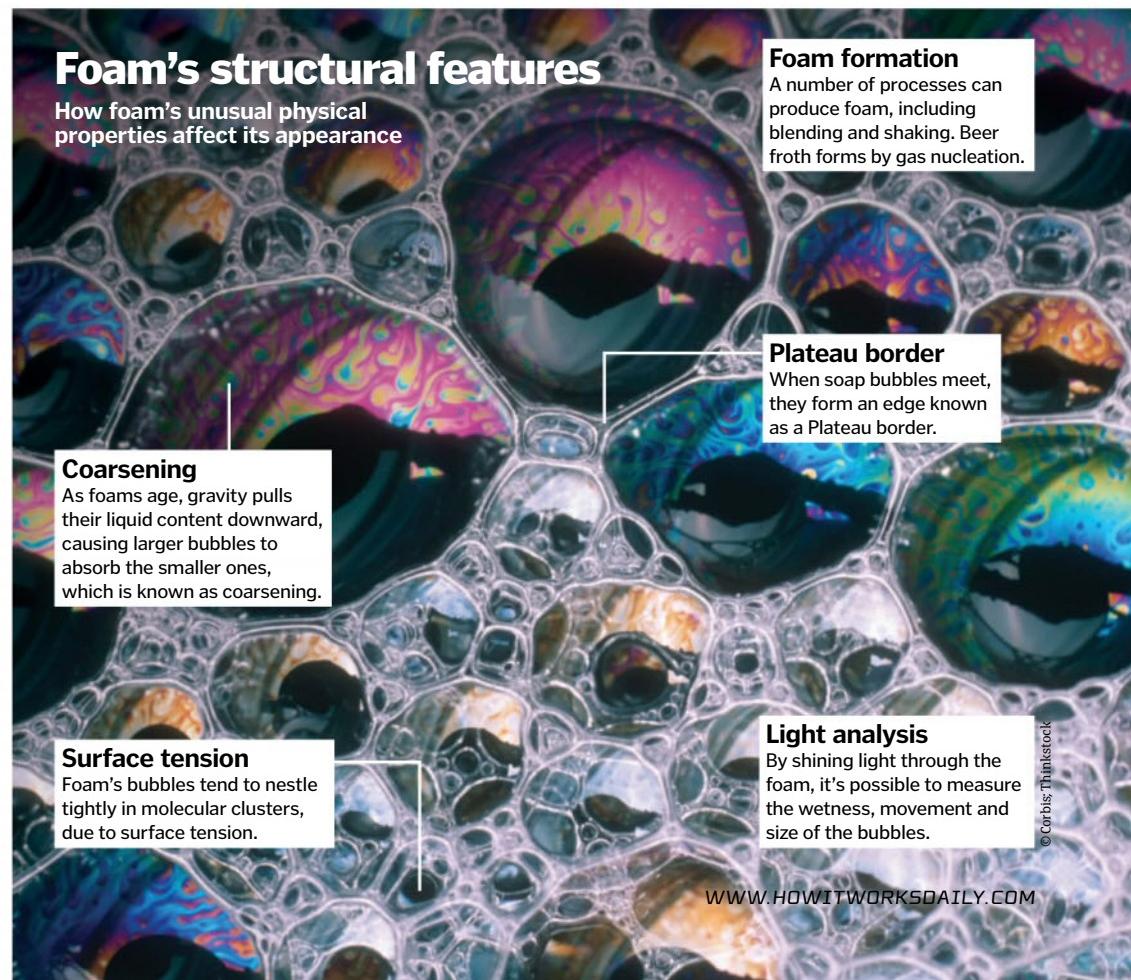
Popping the mystery behind this strange substance

**F**oams are made up of thousands of tiny bubbles, and have a wider range of applications than you would expect. They are used to fight fire, separate ores and manufacture vehicles; one type has even been used to neutralise anthrax.

Upon handling foam, its physical state is somewhat unclear. Although it has qualities of all three states of matter, typical liquid foam is 95 per cent gas and five per cent liquid. Foams contain a surfactant, which prevents the bubbles from immediately popping, by keeping them separate and repelling water.

Foam is far more rigid than you would expect, which is due to something known as jamming. This phenomenon occurs because the foam bubbles are incredibly tightly packed, meaning the bubbles can't move around each other when they are compressed. The pressure within the bubbles will continue to increase as they are further compressed, making the foam appear even more solid.

A study into foam optics and mechanics was conducted on the International Space Station between 2009 and 2010, looking at foam stability and foam coarsening, along with how microgravity affects a liquid's 'foamability'. ☀



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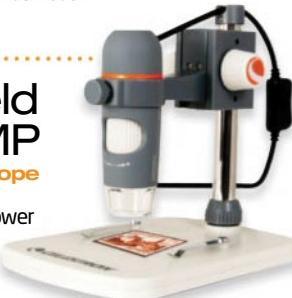
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# The science of singing

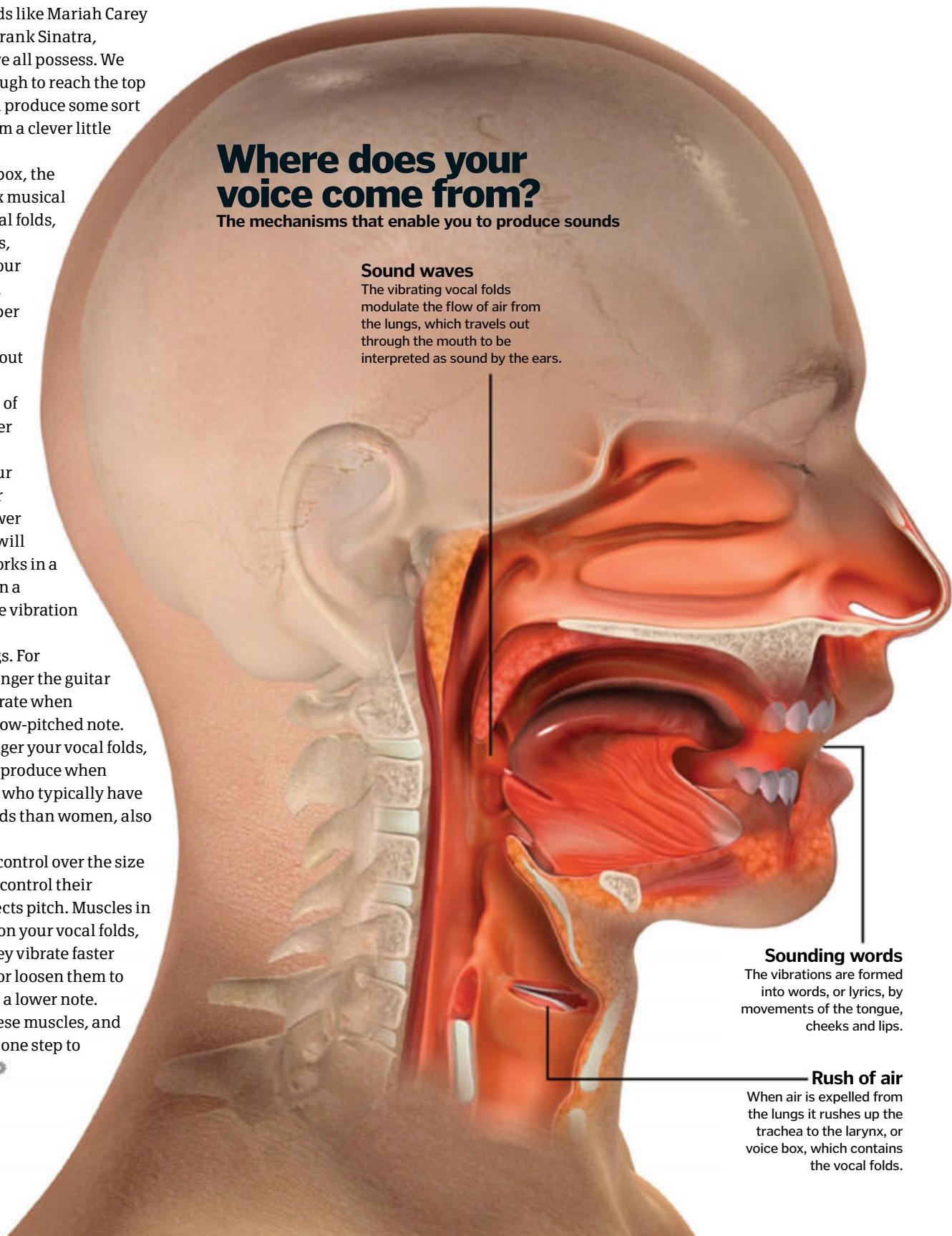
How do some people manage to hit all the right notes?

**F**rom belting out ballads like Mariah Carey to crooning along to Frank Sinatra, singing is an ability we all possess. We may not all be talented enough to reach the top of the charts, but we can all produce some sort of tune, which all stems from a clever little organ in the neck.

Also known as the voice box, the larynx is your own complex musical instrument. It contains vocal folds, better known as vocal cords, which vibrate to produce your voice, but the type of sound created depends on a number of factors.

The amount of air forced out of the lungs controls the volume, so a greater exhale of breath will generate a louder sound, while the pitch is determined by how fast your vocal folds vibrate. A slower vibration will produce a lower note and a faster vibration will produce a higher note. It works in a similar way to the strings on a guitar, with the speed of the vibration influenced by the physical characteristics of the strings. For example, the thicker and longer the guitar strings, the slower they vibrate when plucked, thus producing a low-pitched note. Similarly, the thicker or longer your vocal folds, the lower the sound they'll produce when vibrating. This is why men, who typically have thicker and longer vocal folds than women, also have deeper voices.

While you may not have control over the size of your vocal folds, you can control their tightness, and this also affects pitch. Muscles in your larynx create tension on your vocal folds, and can tighten them so they vibrate faster and produce a higher note or loosen them to vibrate slower and produce a lower note. Learning how to control these muscles, and therefore your pitch, is just one step to becoming a better singer.



# Why are some people naturally good at singing?

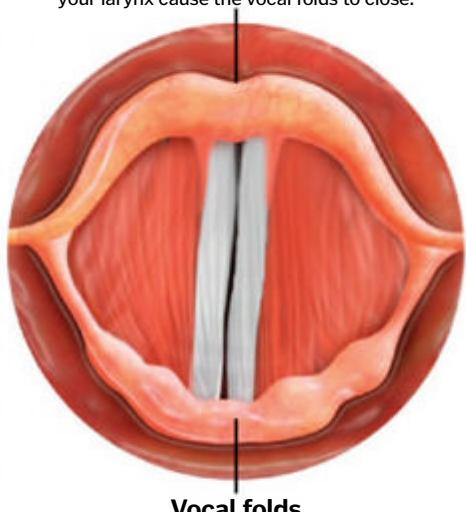
No matter how much practice you have or how good your vocal coach is, there's no guarantee that you'll be able to win *Eurovision*. The fact is some people are just born with a naturally great singing voice. The shape and size of their vocal folds plays a part in this, but so does the measurements of their mouth, throat and nasal cavities. These are the body's natural resonators, meaning they can help enhance the tone and intensity of

the voice. This is what creates the distinctive nasal tone of some country music stars and the more breathy voice of Marilyn Monroe, for example. You may not be able to control the natural tone of your voice, but you can adjust the style by making use of particular resonance chambers in your body. For example, if you want your voice to have an airy quality, try directing the vibrations toward the back of your mouth.



## Speaking and singing

When you speak or sing, the muscles in your larynx cause the vocal folds to close.

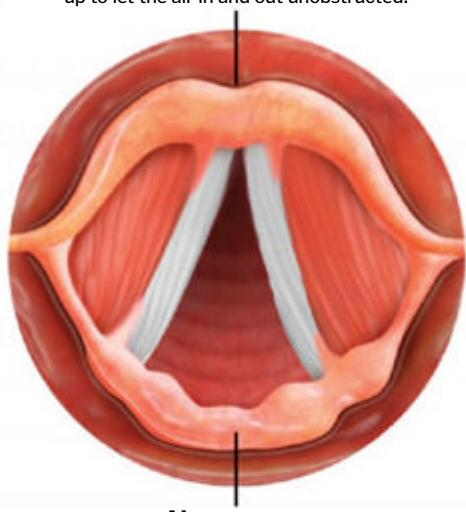


With a bit of practice every day, anyone can become a good singer



## Breathing

When you breathe, the vocal folds open up to let the air in and out unobstructed.



## How can I become a better singer?

Anyone can become a better singer with the right training and enough practice. The problem for most bad singers is the inability to imitate the correct notes. Perceiving the notes isn't the problem, because this is how they recognise tunes in the first place, but when it comes to controlling the tension of the vocal cords to match the same pitch, they often struggle. This is simply a case of poor wiring in the brain, but with plenty of practice the brain can be reprogrammed to give the larynx muscles the correct instructions to produce the right sounds. For many people, inefficient breathing can also hinder their ability to carry a tune. However, by training themselves to breathe by moving their diaphragm – not their chest and shoulders – they can prevent their vocal folds from tightening when they inhale and air from being forced out too quickly when they exhale, thus having better control over their voice.



As the air pressure builds up again behind the folds, they reopen. This process repeats several times a second to vibrate the vocal folds.

# How wrinkles form

Discover how the body's largest organ loses its elasticity over time

**W**rinkles are an inevitable part of the natural ageing process. There are two different types of wrinkles; dynamic wrinkles, which develop due to repeated muscle movements, such as smile lines around the mouth, and static wrinkles caused by environmental factors, lifestyle habits and the ageing process. Static wrinkles are visible even when your face is at rest and often deepen over time. They are caused by a loss of skin elasticity, fat and collagen.

The skin itself is made up of three layers. The epidermis layer on the surface is made up of dead skin cells and protects the body from outside elements such as water and sunlight. Beneath this layer is the dermis, which is responsible for the skin's strength and elasticity, as it's rich in collagen and elastin fibres. The base layer, known as the hypodermis, is where fat cells that give the skin its plump youthful appearance reside.

Over time, wrinkles will start to form on both the epidermis and dermis layers. As we age, our skin cells take longer to divide, which means the skin repairs at a much slower rate than when it's young. As a result of this, the dermis layer will begin to thin out, and fine lines start to form on the epidermis due to a loss of moisture. Eventually, collagen and elastin will break down in the dermis layer, which reduces support so the skin is unable to ping back as quickly when stretched. Fat will also begin to deplete in the hypodermis layer, causing the skin to sag and appear much less plump.



## What causes wrinkles?

The beauty industry makes millions of pounds every year with products that promise to slow down the ageing process and vanquish already visible lines and wrinkles. Unfortunately, wrinkles are unavoidable as we age, but their development can be slowed to some extent with a few preventative measures. Exposure to sunlight is in fact most detrimental to your skin, as ultraviolet rays can break down collagen and elastin fibres in the

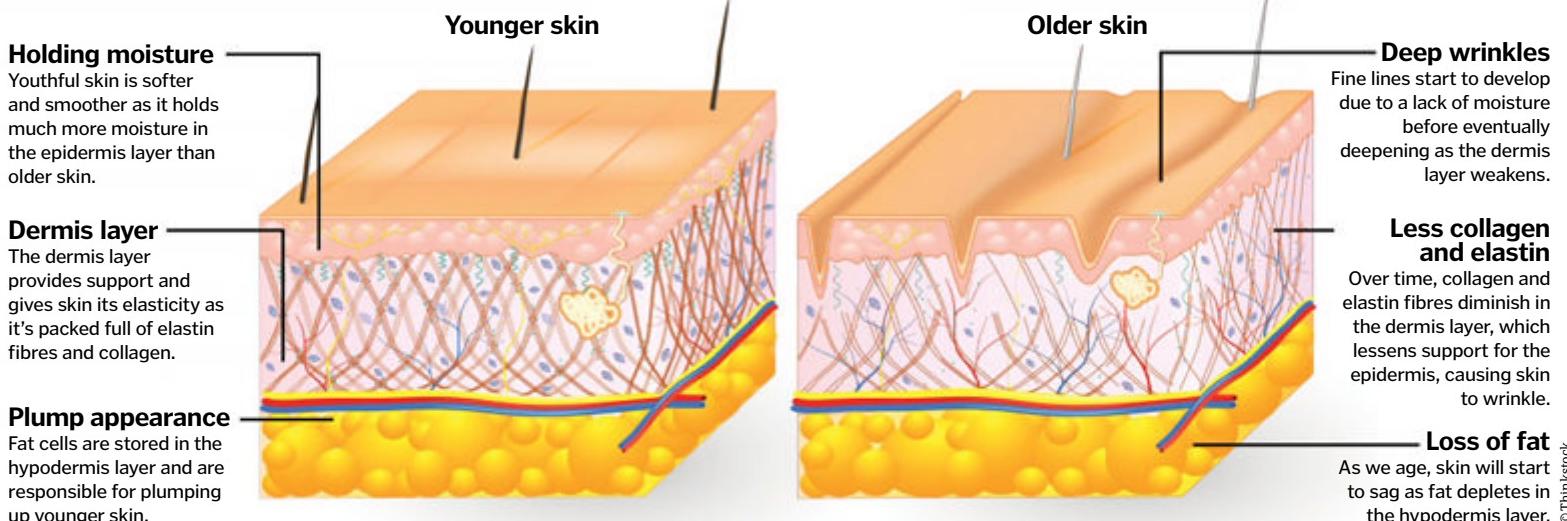
dermis layer, which leads to the skin losing its strength and elasticity. So keeping your skin suitably covered and protected with a high-factor sun cream will help to protect it from harmful UV radiation.

Genetic factors, stress and repeated facial expressions can also play a part in how quickly wrinkles form, while ditching bad habits such as smoking, which reduces blood supply to the skin, will also help delay the onset of fine lines and wrinkles.



## The ageing process

A closer look at how wrinkles form in the skin



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## HOW IT WORKS

PICK OF THE SCORES...

Score dinos, they won't bite

You can score absolutely anything on Just a Score. This month we had fun rating our favourite (and not-so-favourite) dinosaurs in the run-up to *Jurassic World*.

10	HowItWorksmag scored 10 for Ankylosaurus
9	HowItWorksmag scored 9 for Tyannosaurus rex
8	HowItWorksmag scored 8 for Triceratops
4	HowItWorksmag scored 4 for Charonosaurus
3	HowItWorksmag scored 3 for Utahraptor

# How to check your pulse

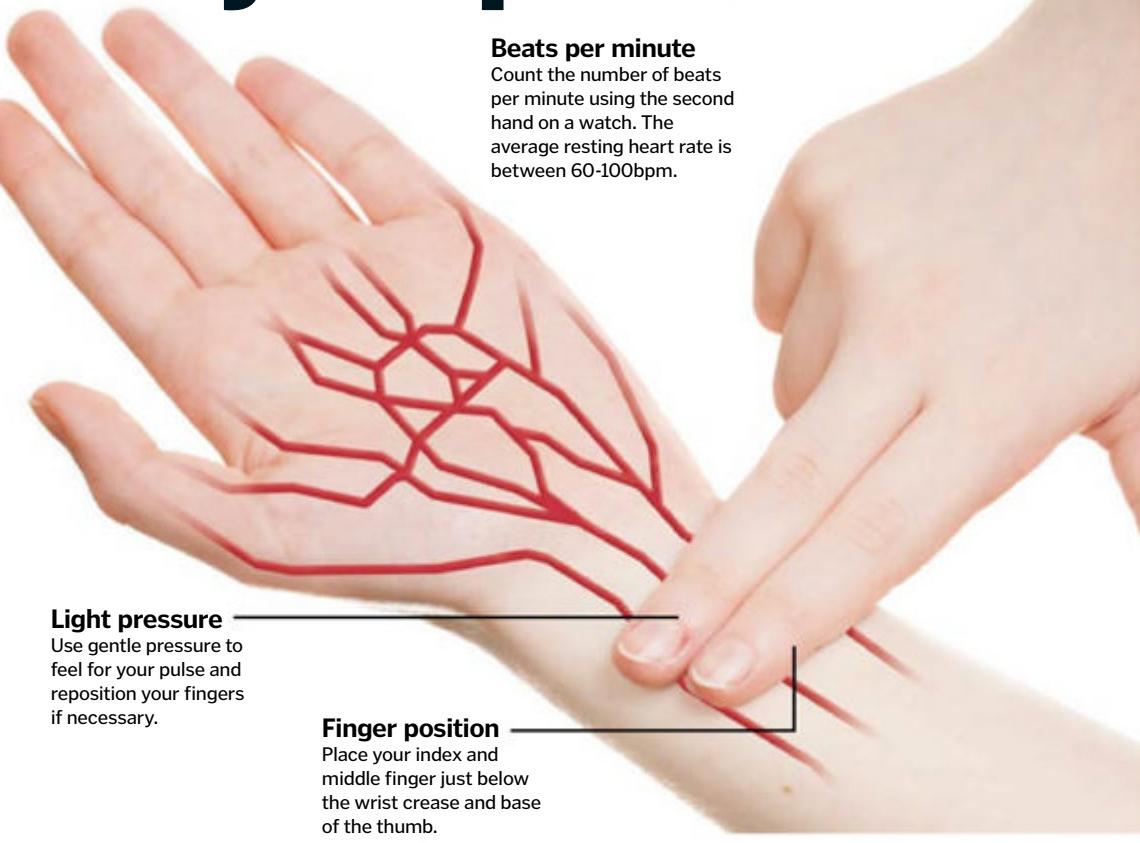
See whether you have a regular or irregular heart rate

**C**hecking your own pulse is a good way to keep track of your heart rate.

Monitoring it while you're resting is the best way to get an accurate reading, as rhythm can increase at different times during the day, especially when you're exercising.

It's possible to check your radial pulse on your wrist or on your neck. This is because arteries pass close to the skin in these areas. To take your wrist pulse, simply turn over one of your hands so that the palm is facing up. Now place the index and middle finger from your other hand below the crease of the wrist, in line with the base of your thumb and next to the tendon. Use gentle pressure and feel carefully for a beating pulse. If you're checking your pulse in your neck, place the same two fingers just below the jawline next to your windpipe.

Once you've located your pulse, use the second hand on a watch to count the number of beats per minute. A normal resting heart rate for an adult should be around 60 to 100 beats per minute.



## Beats per minute

Count the number of beats per minute using the second hand on a watch. The average resting heart rate is between 60-100bpm.

# Science behind household bleach

How a chemical reaction kills bacteria and vanquishes stains

**H**ousehold bleach is popular cleaning product that can be used to disinfect surfaces, remove stains and even whiten clothing. There are many different forms of bleach and two main types, chlorine bleach and non-chlorine bleach. Although chlorine bleach is most commonly used in homes, all bleaches are in a class of chemicals called oxidative agents. This means a chemical reaction called oxidation occurs when bleach comes into contact with certain germs and

stains. When removing a stain from white clothing, for example, bleach will oxidise and break the chemical bonds of a chromophore, which is part of a molecule that has colour. This will essentially prevent the stain from being able to absorb light so that the area appears white like the rest of the garment. The active ingredient sodium hypochlorite in chlorine bleach can also oxidise and kill molecules in germ cells, which is why bleach is also used as an effective disinfectant.



Sodium hypochlorite in bleach oxidises molecules, which helps to remove stains and kill bacteria

# Underwater vision

Learn why refracting light is essential to seeing underwater

**H**uman eyes are not designed to focus well underwater, which is why objects appear blurry below the waves. On land, our eyes rely on refraction in order to focus correctly. You can observe refraction by placing a straw in a glass of water; from the surface it will appear to bend. This is because light travels in a straight line through a consistently dense medium, but when it passes between the air and a medium of different density, such as water, it bends or refracts at the boundary between the two, before continuing to travel on a straight path.

The lens in a human eye works in a similar way, as refraction occurs when light travelling through the air passes into the cornea at the front, which has a much higher density. Unlike the flat surface of water, however, which bends all light rays in the same direction, the eye lens is curved, which means light is bent at different angles in order to create a focused image on the retina at the back. Human eyes can't focus properly underwater because of this, as light rays travelling through the water are barely bent when they pass through the cornea and inside lens. This is why goggles give you a clearer view, as you're placing a boundary of air between the water and your eyes, enabling refraction to occur.



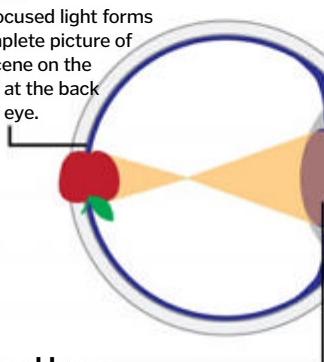
Human eyes need to refract light in order to focus, which is why the underwater world appears blurry without goggles

## How humans see

Take a closer look at how the human eye creates an image on land and underwater

### Retina

The focused light forms a complete picture of the scene on the retina at the back of the eye.



### Cornea

Once light reaches the cornea it is refracted and bent, as the cornea is denser than air.

### Light rays

Light travels in a straight line through the air before passing through the cornea.

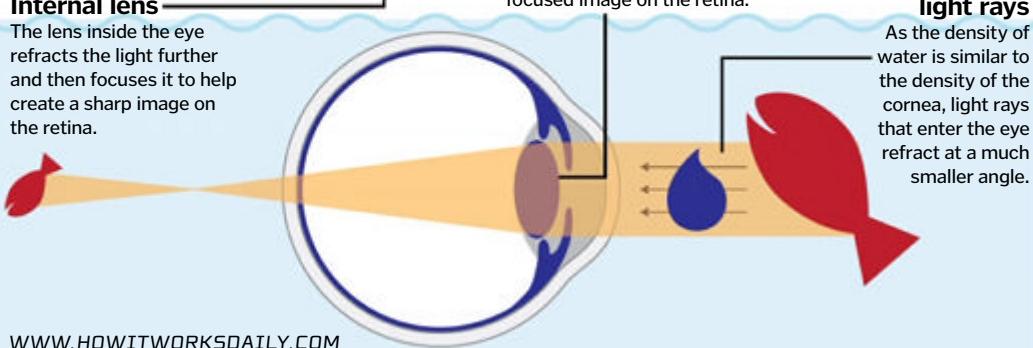


### Focusing

In water, the internal lens will refract the light slightly, but not enough to create a clear focused image on the retina.

### Internal lens

The lens inside the eye refracts the light further and then focuses it to help create a sharp image on the retina.



## How fish can see clearly underwater

Fish are well adapted to living and seeing in dark underwater conditions. Their large convex eyes enable them to gather more light at great depths. However, unlike human eyes, light is not refracted or bent as it enters the cornea. In fact, refraction occurs in a fish's eye when light passes through the spherical internal lens, which is much thicker than a human's, enabling more light to be refracted as a result. The lens of a fish eye is also fixed in shape; so in order to focus on objects near or far away it will move backward and forward as opposed to changing shape.

Some species of fish also have a thin layer of tissue that acts like an eyelid, which covers the front of the eye and helps to protect the cornea from being scratched when they swim at speed.



### Underwater light rays

As the density of water is similar to the density of the cornea, light rays that enter the eye refract at a much smaller angle.



# VTOL drones

From the humble helicopters of yesterday, to the robotic drones of tomorrow: vertical lift technology is on the rise

Almost as far back as humans have been dreaming of inventions for flight, they have been envisioning craft capable of vertical takeoff and landing (VTOL). Leonardo da Vinci is responsible for some of the earliest designs for today's most common VTOL aircraft – the helicopter. It may have only been an untested imagining of a flying machine that never got off the ground, but this so-called 'aerial screw' harnessed the essential principles of lift through air compression – utilising a corkscrew design.

Though scores of inventors and pioneers attempted to take to the skies in their own prototypes, over the following five hundred years not much further progress in VTOL flight was made. However, though the gyrocopter design was left well behind, the Italian genius's principles of flight in essence remained much the same.

The beginning of the 20th century saw the age of flight dawn, and by 1907 some of the first-ever successful VTOL tests took place in France. Aviation pioneers Jacques and Louis Breguet, as well as Paul Cornu, had developed

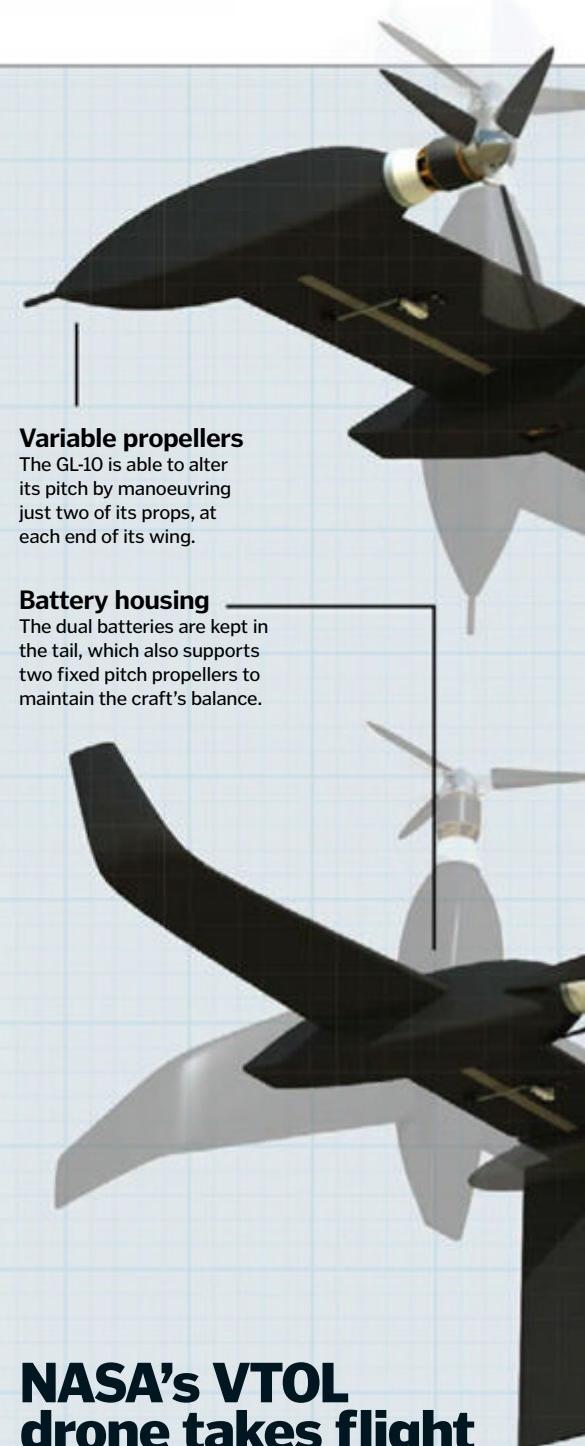
VTOL craft capable of hovering some feet off the ground for a short length of time – the first baby steps of vertical flight.

The following decades saw aviation technology race skyward, with designs popping up all over the globe. Though the Great War saw a huge demand for newer, faster and more-efficient aircraft to fight the enemy, helicopter designs were largely ignored until the 1940s and the Second World War. Nazi Germany used some early helicopters for reconnaissance, transportation and medical evacuation, but it wasn't until 1944 that the first mass-produced helicopter was revealed.

Hundreds of engineer Igor Sikorsky's R-4, R-5 and R-6 helicopter models were built during the final year of WWII to aid the Allies, and by the end of the war the VTOL craft was quickly gaining acclaim. Unlike da Vinci's gyrocopter design, this modern helicopter used rotor-blades to rapidly compress air downwards to create the necessary lift, and a tail rotor-blade to prevent the aircraft spinning.

As the world cooled into the threatening Cold War, it was the opinion of many that VTOL craft

The GL-10 on its maiden test flight in 2014, tethered by a safety cable



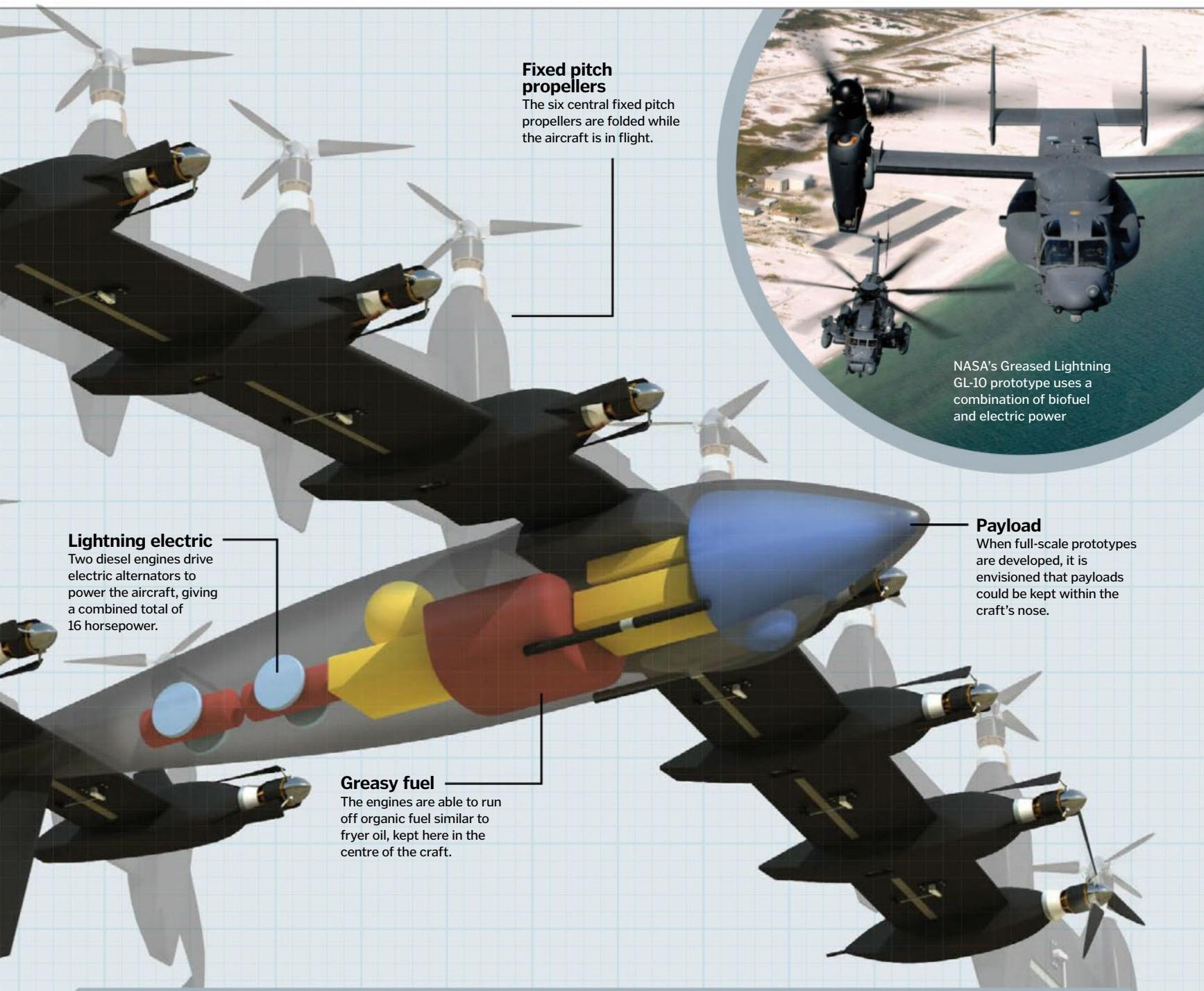
## NASA's VTOL drone takes flight

NASA's hybrid-electric craft, dubbed Greased Lightning GL-10, may only have a three-metre (ten-foot) wingspan, but it has already shown promise for stretching VTOL technology much further. Its ten distinctive propellers provide maximum lift efficiency while travelling vertically, before both wing and tail panels tilt to transfer GL-10 to horizontal flight. Only two propellers do all the work at this point, to save energy, while the rest fold back aerodynamically.

It's the combination of biofuel and electric power that gives the craft its nickname – the grease of the fuel and the lightning of the batteries. The hybrid design of the engine means it's far less cumbersome than a standard jet or combustion engine, enabling not only a sleeker design but also far less wasted energy.

While the GL-10 prototype is obviously far too small for transporting any significant payload, NASA has revealed its GL-10 represents a 'scale-free' design, meaning the weights and measures of Greased Lightning could work in much larger sizes. This means that craft similar to GL-10 may become more and more common if further tests are successful.

**DID YOU KNOW?** Because the Osprey derives its thrust from its twin tilt rotors, it isn't considered either a plane or a helicopter



## The most famous VTOL aircraft



**V-22 Osprey**  
Developed by US manufacturers Bell and Boeing, the Osprey's two unique tilt-rotor propellers provide its VTOL ability. They also enable the craft to reach speeds of up to 500km/h (311mph).



**BAE Sea Harrier**  
Developed during the 1970s, the Harrier Jump Jet utilises four separate vector nozzles to direct its engine thrust. In this way it is able to transition from vertical to horizontal flight, and even hover.



**Boeing CH-47 Chinook**  
Considered one of the great workhorses of modern militaries all over the globe, the Chinook's twin-rotor design enables it to transport hefty payloads of up to 10,886 kilograms (24,000 pounds).



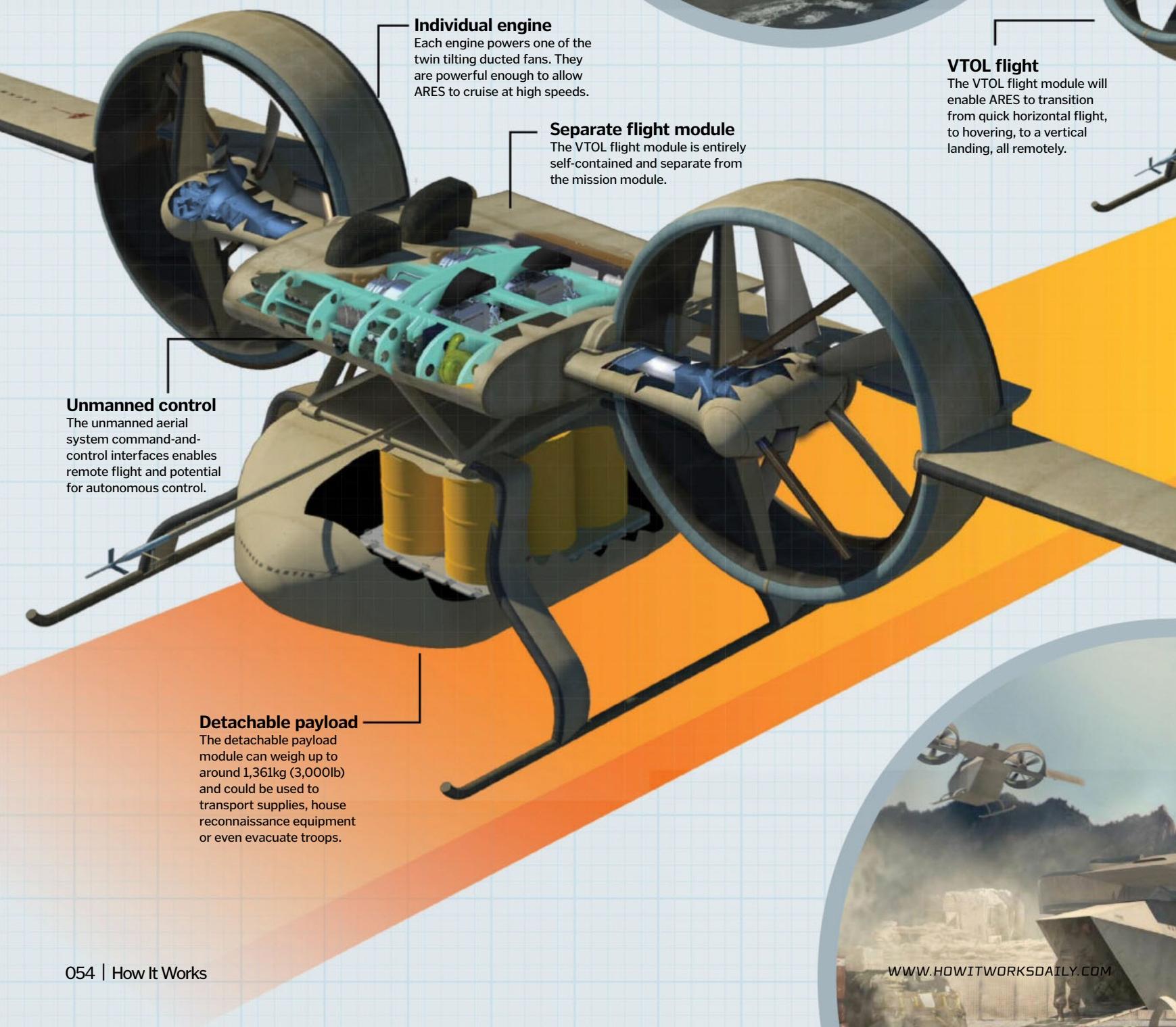
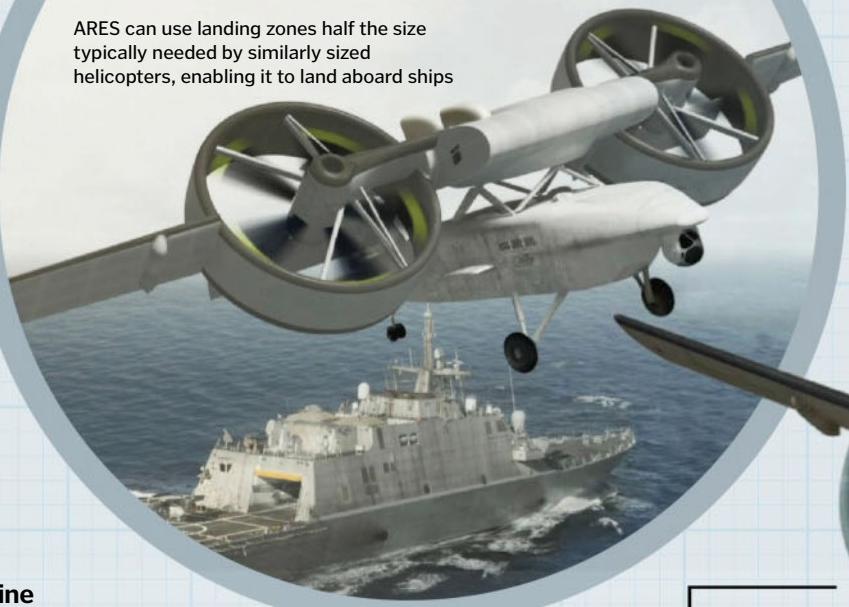
# Unmanned VTOL goes to war

How DARPA's Aerial Reconfigurable Embedded System (ARES) could change the face of frontline combat

In a bid to overcome the problem of transporting supplies across difficult and often dangerous battlefield terrains, DARPA has turned to unmanned VTOL drones. The ARES design is capable of carrying a range of payloads; from supplies, to reconnaissance equipment, to evacuated casualties.

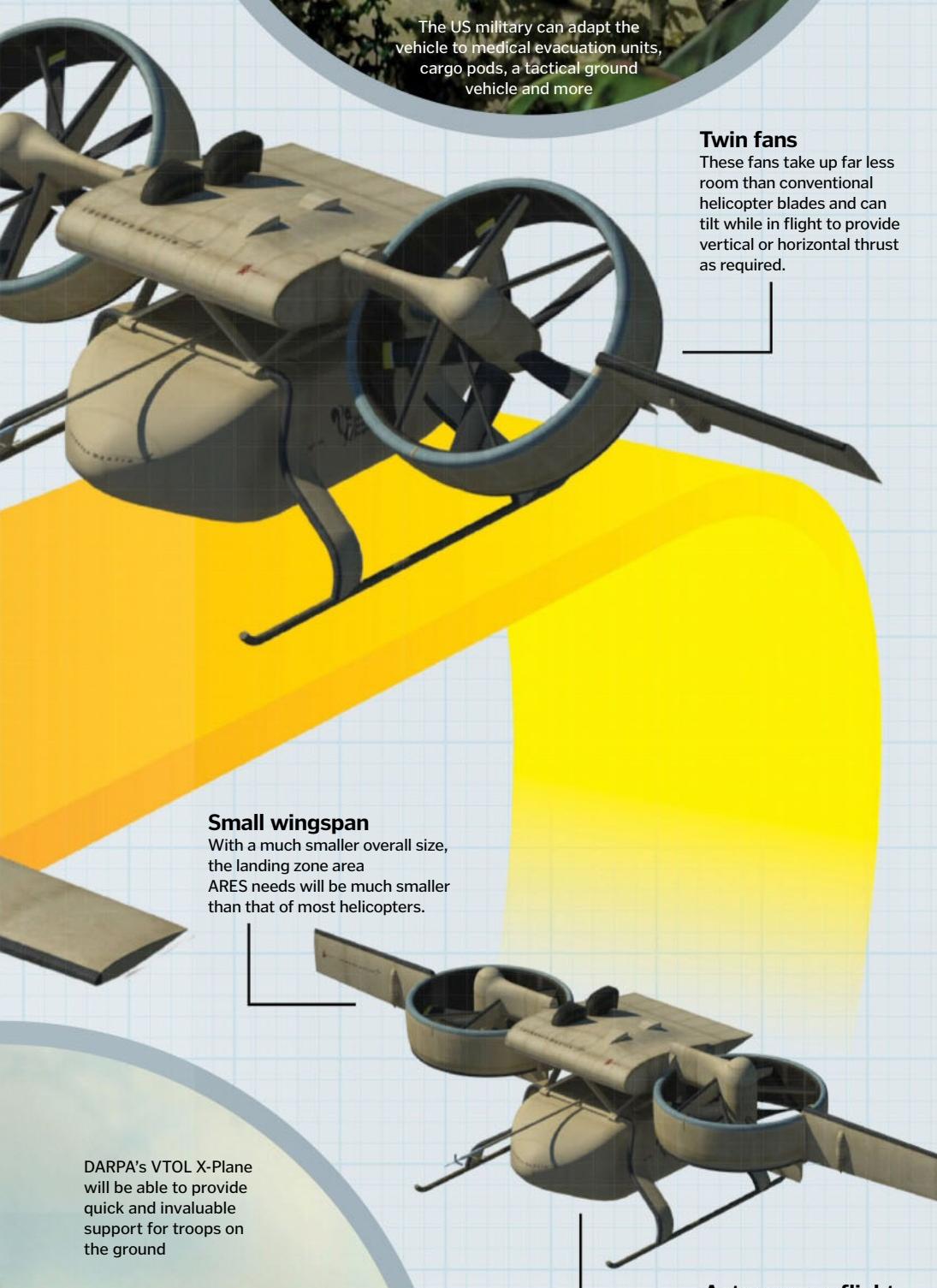
An onboard computer will be capable of selecting optimal routes from its home base to the troops in the field. It will even be able to select a landing zone completely by itself, providing quick and invaluable support to troops on the ground.

ARES can use landing zones half the size typically needed by similarly sized helicopters, enabling it to land aboard ships





The US military can adapt the vehicle to medical evacuation units, cargo pods, a tactical ground vehicle and more



#### Small wingspan

With a much smaller overall size, the landing zone area ARES needs will be much smaller than that of most helicopters.

#### Twin fans

These fans take up far less room than conventional helicopter blades and can tilt while in flight to provide vertical or horizontal thrust as required.

#### Autonomous flight

With further development it's hoped that ARES will be able to fly and land all by itself, using sensors to select optimal routes and landing locations.

DARPA's VTOL X-Plane will be able to provide quick and invaluable support for troops on the ground

would be the future. In a world potentially ravaged by nuclear blasts, obliterating any obliging runways, it was thought a craft with the ability to take off and land anywhere would rule the skies. In time, bizarre VTOL aircraft such as the Lockheed XFV Salmon – an experimental fighter – and even the flying saucer-inspired Avrocar were tested by the US military, but most failed and were discontinued. Among the only VTOL aircraft to make it out of the Cold War with flying colours was the BAE Sea Harrier.

Also known as the Harrier Jump Jet, this plane was the first successful VTOL jet aircraft. Four vectoring nozzles direct the jet's engine thrust anywhere within a 90-degree radius, enabling the plane to fly across vertical and horizontal paths, transitioning in mid-air and even hovering.

The Harrier's VTOL ability was ideal for working on aircraft carriers – the floating fortresses of the waves. Its Rolls-Royce turbo fan engine, coupled with unparalleled flexibility and the latest weapons arsenal, made the jet a formidable opponent.

One other vehicle to emerge from the Cold War was the V-22 Osprey. Developed by Bell and Boeing, this vertical-lift transport aircraft is packed with twin tilting rotors capable of both hovering and landing like any helicopter, or transitioning to fly like a turboprop airplane.

With a range of over 400 nautical miles (740 kilometres/460 miles) and the ability to rapidly transport over 30 troops, the Osprey serves the US Marine Corps in key insertion and extraction missions. It even has the ability to fold its 25-metre (82-foot) wingspan away, condensing down to just its 5.6-metre (18-foot)-wide fuselage. This makes it invaluable for storage on aircraft carriers.

With each new generation come fresh challenges for engineers to overcome. Today's military minds face the problems of producing aircraft that are not only cost-effective and incredibly flexible, but also smart. Into the future, contractors and state defence ministries are increasingly turning towards VTOL technology for use with military drones.

While the computer power behind these machines may be cutting-edge, the physics lifting them into the air and setting them safely back on the ground remain the same.

Either by remote operation or autonomous flight, VTOL drones will be capable of performing a range of transport, reconnaissance, or even offensive missions. We've shown you a few exciting visions – from the best and brightest in the aviation industry – set to launch VTOL technology into the next generation.



# Twin-clutch gearboxes explained

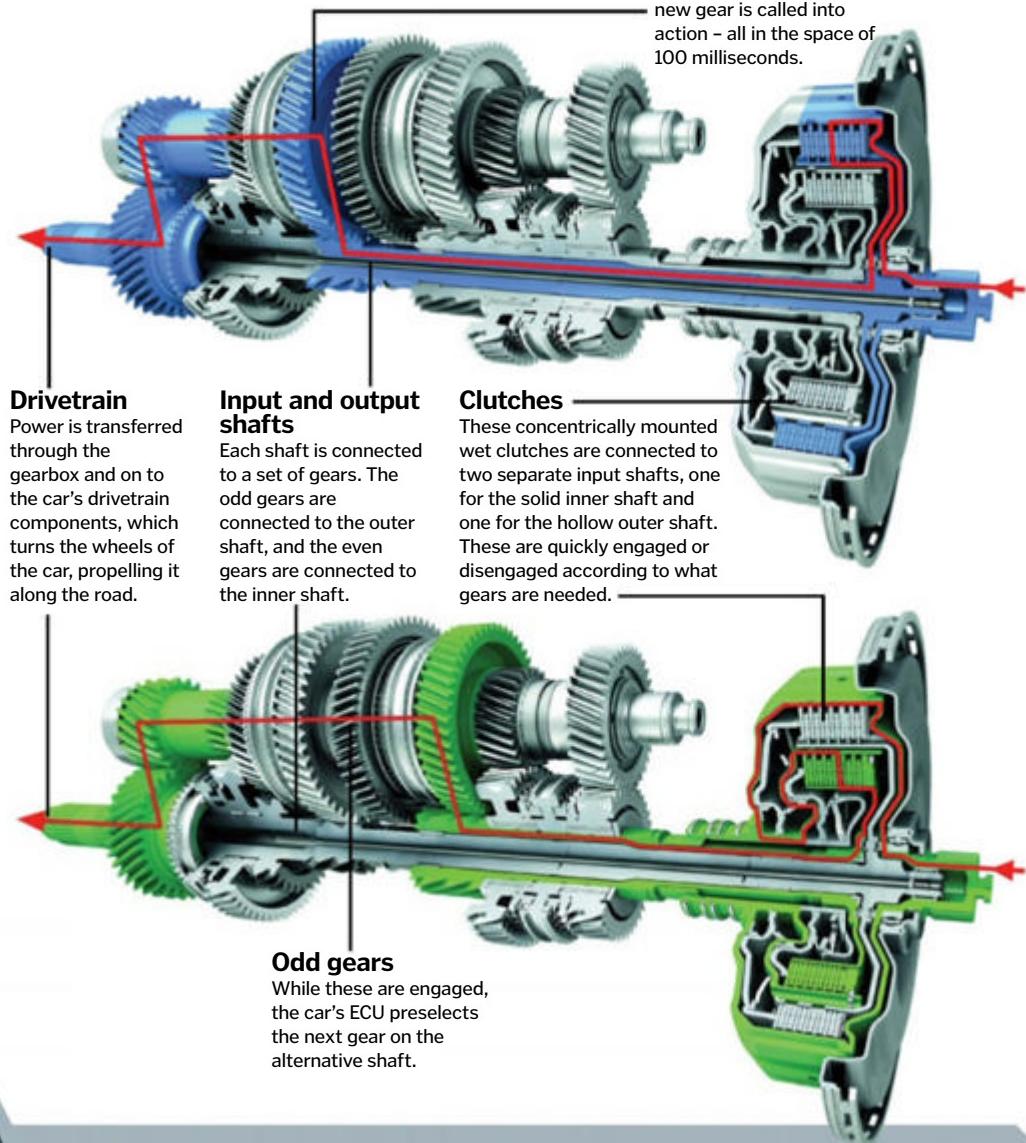
They are a common feature in today's supercars and here's why

As supercars get faster and faster, with 0-100-kilometre (0-62-mile)-per-hour times of less than three seconds, manufacturers are now looking at ways of making gains for their cars to cover even more ground in even less time. An area that has been developed a lot in supercars in recent years are gearboxes, where a lightning-quick gear change is absolutely essential if the car is to maintain linear power delivery when accelerating to 100 kilometres (62 miles) per hour and far beyond.

To provide this super-quick shift, manufacturers such as Porsche, Audi and Lamborghini have produced a complex yet exquisite 'double-clutch' semi-automatic gearbox that substantially reduces the time it takes to shift up or down a gear. This technology works by effectively splitting the gearbox in two, with a concentrically mounted clutch on the end of two separate input shafts. The odd gears are on one shaft and the even gears are on the other. When a new gear is selected, the supercar's on-board computer preselects the next gear needed on the other shaft according to driving style and conditions, so when it is time to change gear, the cog in question takes mere milliseconds to engage with the drivetrain, making sure that mighty power from the engine is fed to the wheels as efficiently and quickly as possible. ☀

## Inside a twin-clutch gearbox

Here's how a twin-clutch gearbox works in a semi-automatic Porsche 911



### Even gears

When the gear change happens, the clutches are quickly swapped and the new gear is called into action - all in the space of 100 milliseconds.

### Clutches

These concentrically mounted wet clutches are connected to two separate input shafts, one for the solid inner shaft and one for the hollow outer shaft. These are quickly engaged or disengaged according to what gears are needed.

### Odd gears

While these are engaged, the car's ECU preselects the next gear on the alternative shaft.

## Automatic vs manual gearboxes

The purists will always favour the better driver involvement offered from the physical 'throw' action when changing gears with a gear stick, but the reality is that, as cars become ever faster and more powerful, automatic gearboxes are inevitably the future. The reason for this is threefold: they allow for quicker gear changes as we've just discovered, plus they're more economical as the car's on-board computer will always select new gears to keep fuel usage

down, while a human can become lazy or forget to change gear according to these parameters. Then there's the safety and comfort factor: as cars produce more power, a bigger clutch is needed to transfer the power to the gearbox, which usually results in a very heavy clutch pedal on supercars. An automatic gearbox takes away the clutch pedal, meaning you can drive the car in comfort without giving your left thigh an excessive workout!



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W A T C H E S



# Behind the wheel of the Porsche 919 Hybrid

Examine the vehicle Porsche has tasked with winning the 2015 Le Mans title

The 24 Hours of Le Mans is the oldest active endurance race in the world. It has been held every year since the inaugural race in 1923 and is often referred to as the 'Grand Prix of Endurance and Efficiency'. Keeping a car running for 24 hours is no mean feat; excellent fuel, tyre and braking efficiency is a must if you want to stay out of the pit lane. The race is also very demanding for the drivers. They form part of a team of three, often driving for two hours at a time, which challenges them both physically and mentally. During the 24 hours, the competitors will typically cover distances of over 5,000 kilometres (3,107 miles). The record distance of 5,410.71 kilometres (3,362.06 miles) was set in 2010, which is the equivalent of completing a Formula One race 18 times back to back.

Porsche is the most successful manufacturer in the history of Le Mans. It's been the overall winner 16 times, however recent dominance by Audi, who has won 13 of the last 15 Le Mans, has left Porsche looking to rediscover its winning formula. This is why it's redesigned the 919 Hybrid, which is, according to Porsche, 85 to 90 per cent brand new compared to the 2014 version. The 2015 Porsche 919 Hybrid has been thoroughly tested, clocking an impressive 26,675 kilometres (16,575 miles) on four different race tracks. It features a vastly improved engine system; the electric motor's performance has been increased by a third, meaning the 919 Hybrid will race in the eight-megajoule category for the first time this year. Having become lighter, more robust and easier to handle, designers hope the new 919 Hybrid's improved efficiency will lead Porsche to their 17th Le Mans title. ☀

There will be three 919 Hybrids racing in three different colours during Le Mans 2015



## Under the hood

See how the Porsche 919 has been engineered for outstanding efficiency and endurance

### Protective cockpit

The new 919 Hybrid has a more spacious cockpit, strengthened with side panels made from monocoque, a material similar to bulletproof vests.

### Front axle motor

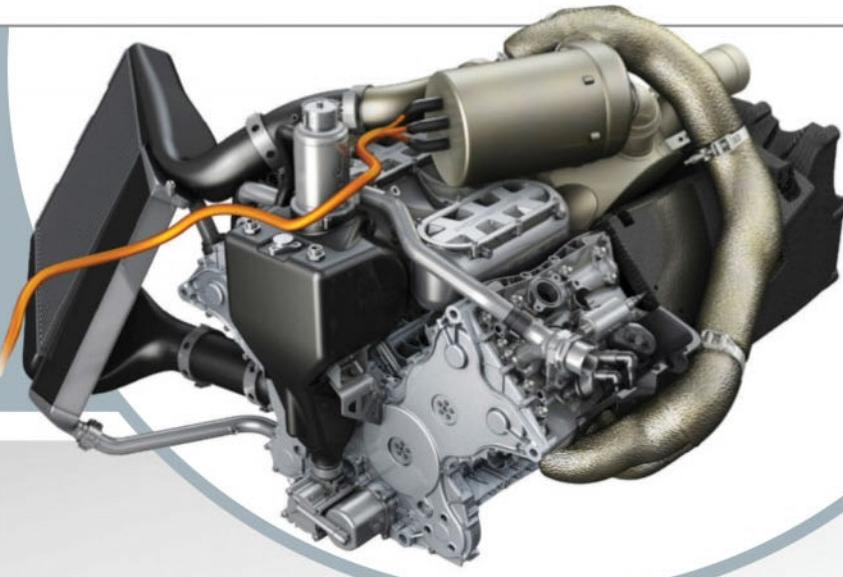
The car's 400-horsepower (298-kilowatt) electric motor is located on the front axle. It charges the battery by recuperating energy during braking.



## The V4 petrol engine

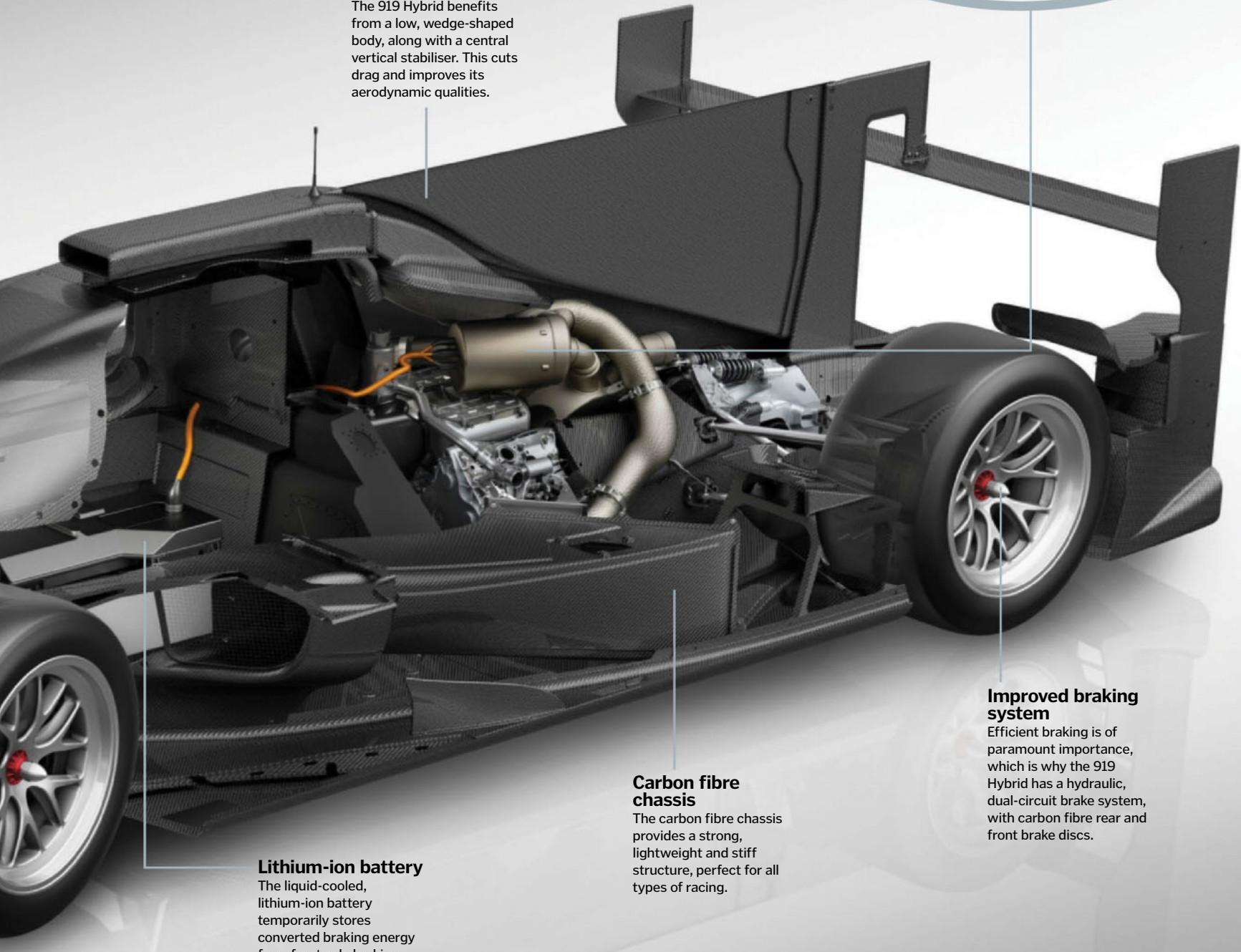
At the heart of the 919 Hybrid is a turbocharged, gasoline-powered engine that sends power straight through to the car's rear wheels. It contains four cylinders, which work together to produce 500 horsepower (373 kilowatts) and revs at 9,000rpm – this is pretty impressive for a two litre engine. Also located here is the car's

gearbox, along with a generator spun by the turbocharger. The engine is mainly made of aluminium, with magnesium and titanium incorporated within it, achieving an ideal weight for the car. Combined with the 919 Hybrid's two energy recuperation systems, it means that altogether the V4 makes for a very efficient race-car engine.



### Aerodynamic bodywork

The 919 Hybrid benefits from a low, wedge-shaped body, along with a central vertical stabiliser. This cuts drag and improves its aerodynamic qualities.



### Lithium-ion battery

The liquid-cooled, lithium-ion battery temporarily stores converted braking energy from front axle braking, along with the converted exhaust-gas energy.

### Carbon fibre chassis

The carbon fibre chassis provides a strong, lightweight and stiff structure, perfect for all types of racing.

### Improved braking system

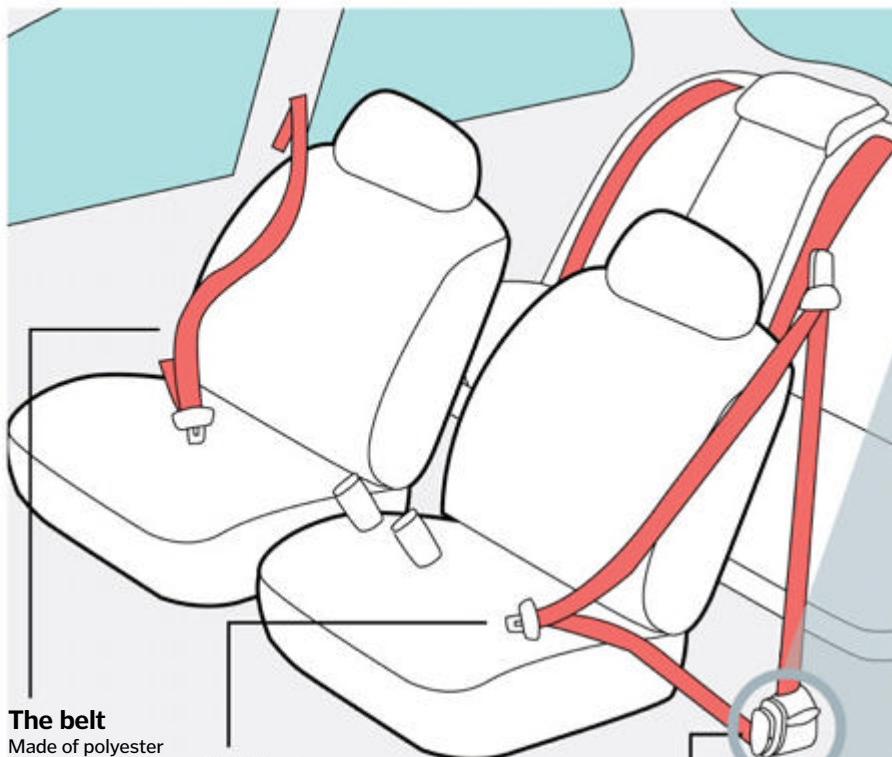
Efficient braking is of paramount importance, which is why the 919 Hybrid has a hydraulic, dual-circuit brake system, with carbon fibre rear and front brake discs.



# How seat belts keep you safe

Here's how a safety belt works to protect you in the event of a collision

Seat belts are simple to use, relatively comfortable and extremely effective at keeping you safe



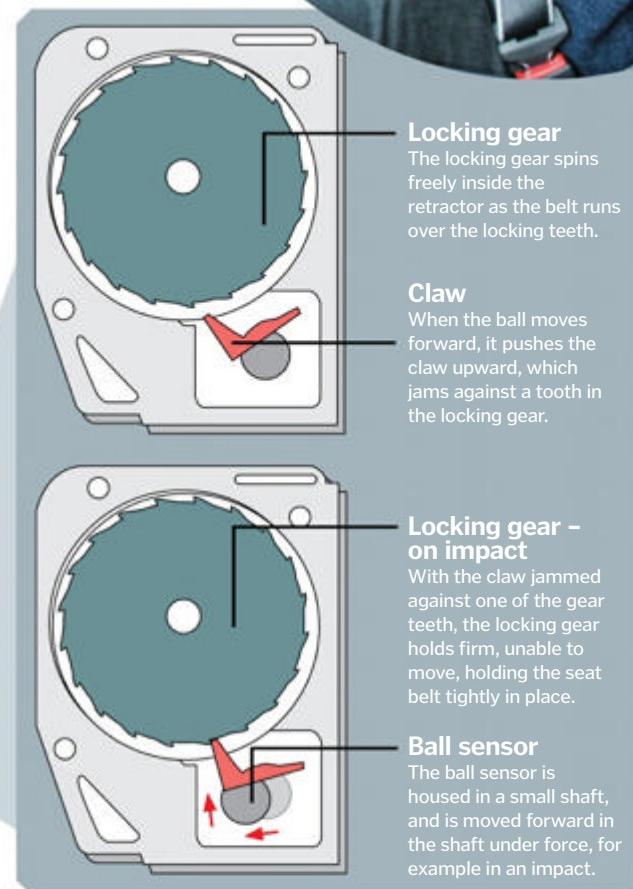
**The belt**  
Made of polyester webbing, this is tough and durable, yet smooth to touch – crucial, as it is strapped over the torso.

#### Belt fastener

The clip at the end of the belt is secured into the fastener, which is attached at the bottom of the seat and holds the belt in place.

#### Retractor

Attached either to the seat, adjacent to the fastener, or holed in a car's B pillar, the belt runs through this mechanism that reacts in an accident.



**Locking gear**  
The locking gear spins freely inside the retractor as the belt runs over the locking teeth.

**Claw**  
When the ball moves forward, it pushes the claw upward, which jams against a tooth in the locking gear.

**Locking gear – on impact**  
With the claw jammed against one of the gear teeth, the locking gear holds firm, unable to move, holding the seat belt tightly in place.

**Ball sensor**  
The ball sensor is housed in a small shaft, and is moved forward in the shaft under force, for example in an impact.

# The art of emergency vehicle lighting

Everybody recognises the blue flashing lights used by the emergency services, but do you know how they work?

Fixed to the top of police, fire and ambulance service vehicles, flashing blue lights are deployed in the event of an emergency. Their bright flashes grab the attention of other road users from a distance, allowing them to take evasive steps in good time to make sure the emergency vehicle can pass through safely and quickly, even in heavy traffic, which is crucial when responding to an emergency call.

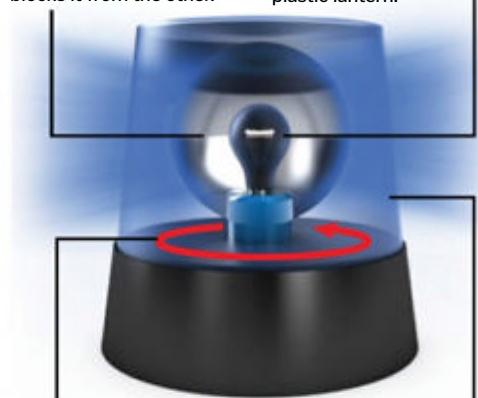
Although brighter, more efficient blue LED lights are now commonplace on police cars, ambulances and fire engines, the old-fashioned

method of using a see-through unit with a single light bulb inside has long been a trusted ally of the emergency services – and its magic is in the illusion it creates.

Of course, bulbs can't keep flashing on and off for long periods or they'll blow, so the illusion is created by a rotating base with a vertical reflector affixed to it, moving around a fixed light bulb. The reflector redirects light outward from one side, while blocking the light out to the other. When the base is rotated fast, this creates the 'on-off' illusion of a flashing blue light atop an emergency vehicle.

**Reflector**  
This bounces light in many directions on one side and blocks it from the other.

**Bulb**  
The white bulb is fixed to the roof of the see-through plastic lantern.



**Light base**  
The base of the light rotates continuously when in operation, moving the reflector around the bulb.

**Lantern**  
Believe it or not, the bulb isn't blue. It's white, and the lantern is coloured in order to produce the bright blue light.

# Happy animals and human smiles... a visit is worth the miles!

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*"Dairy production has come a long way since the days of milking by hand"*

# On the farm

We step inside the milk machine to find out how a modern dairy farm works

**W**hen you pick up a pint of milk from the shop, you probably don't consider how it got there. Of course, we all know that milk comes from cows, but what about the hard work that goes into raising, feeding and milking them? **How It Works** went to visit Knaveswell Farm in the beautiful Dorset countryside, to find out how a dairy farm is run and lend a helping hand in the milking shed.

Dairy production has come a long way since the days of milking by hand. These days, machines are used to help the farmer milk several cows at once. This speeds up the milking process to produce an average of 15,837 pints (9,000 litres/2,377 gallons) from each cow per year.

Usually some manual labour is still required, as the farmer has to clean the cow's udders and attach the teat cups for milking. However, some farms now have fully-automated systems that use laser-guided robotic arms to do this unaided. Some can even send milking updates to the farmer's smartphone, so they never even have to set foot in the milking shed.

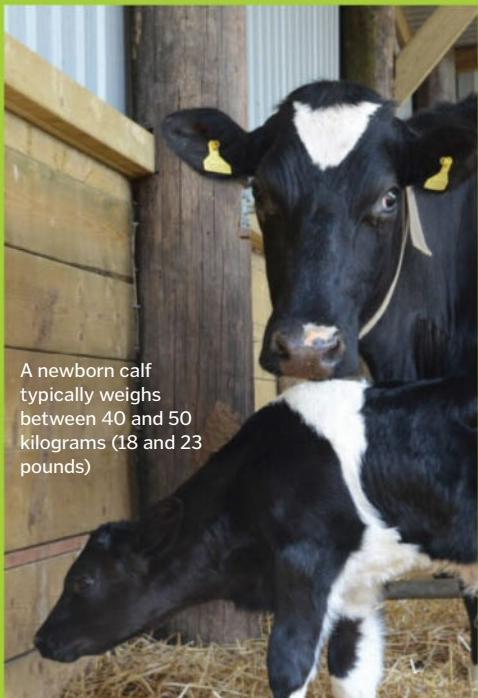
Most farmers don't have it so easy though, and during our visit we found out first hand about the long and demanding daily routine of feeding and milking required. Then, at the end of each day, the milk is collected from the farm and distributed around the country to be bottled and sold, or used to make other products such as ice cream and butter.

It's not just milk that is produced on a dairy farm, though. Male cows are reared for their meat to provide the farmer with an extra source of income, and crops are grown as a source of food for the livestock. An organic farm will stick to using natural fertilisers, such as the cows' dung, and nothing else to nourish the crops, while a conventional farm might use pesticides and artificial fertilisers to aid growth.

Over the next few pages, you'll discover what a day in the life of a farmer is really like, and the technology they use in a modern milking shed. Running a dairy farm is certainly time-consuming and labour-intensive, so next time you pour milk on your cereal, spare a thought for the cow and dairy farmer that got it there.

# Life of a dairy cow

From birth to milking, find out how a dairy herd is managed



## Calving

Female cows only produce milk after they have given birth, so it is important that they regularly produce young to keep up milk production. This is usually achieved through artificial insemination rather than natural conception, as male cows, or bulls, are typically sold for their meat. Once pregnant, the cow will carry her calf for nine months before giving birth.

## Growing up

When the calf is born, it is kept with its mother for 24 hours so that it can feed from her. This is important because the first milk produced after calving contains colostrum, which is rich in energy, protein and antibodies. The calf is then separated from its mother, but continues to be fed milk until it is six to eight weeks old, when it is weaned onto solid food.

## Joining the herd

At around two years old, female cows are ready to join the milking herd. During the winter months they are kept inside, but in the summer they roam the fields and eat the grass, the cheapest form of food available. They are milked twice a day for ten months of the year, and for the remaining two months they produce calves of their own.

## A farmer's day

The demanding routine of a dairy farmer



**12:00pm**  
The farmer checks the health of the herd and then manages the crops and food stocks.



**11:00am**  
Any dung produced by the cows indoors is cleared out and spread on the fields as fertiliser.

**8:00am**  
After milking, the cows are fed. In summer they graze on grass outside and in winter they are fed silage indoors.



**4:00pm**  
The milking process begins again. A typical dairy cow will produce 30 litres (eight gallons) of milk per day.



**5:00am**  
The farmer herds up the cows ready to be milked. Milking can take one to three hours, depending on the size of the herd.



**6:00pm**  
The herd is fed again, then beds down in the barn during winter, or goes back into the fields during summer.

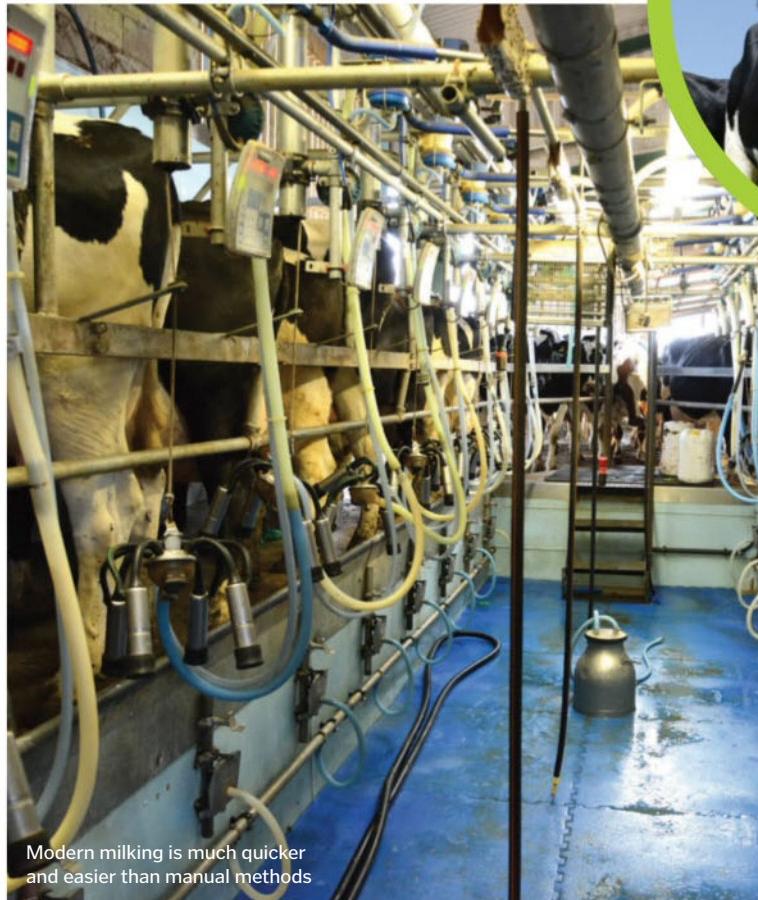


# The milking process

## Take a look inside a modern milking shed

When it's time to be milked, the cows assemble outside the shed and enter one by one on either side. Once they are standing at a milking station, the farmer cleans their udders and extracts some milk to check that it is free of blood and other impurities. Next, the cluster of teat cups is attached, and the cow is left to be milked. It can take a couple of minutes for pulsating air to squeeze out all the milk, then when no more is left, the suction stops and the teat cups automatically detach. As the cow's teats take a further 30 minutes to close up again, an iodine dip is applied to prevent infections. Then the rest of the milking equipment is thoroughly cleaned and sterilised too.

If a cow is sick, their milk is kept separate from the rest and either thrown away or fed to the other animals on the farm. Nevertheless, the milk in the bulk tank is still tested each time it is collected, to make sure there are no antibiotics or other impurities present. If there are, then the entire supply must be thrown away as it is unfit for human consumption.



## Advertorial

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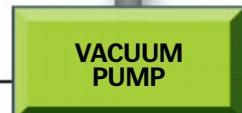
## Milk machine

The tech that milks the cows so the farmer doesn't have to



**Vacuum tank**  
The vacuum level is monitored and more air can be let into the system if it gets too high.

A display helps the farmer keep track of how much milk each cow produces.

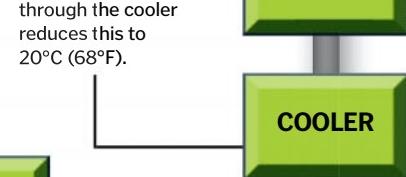


**Vacuum pump**  
A pump removes any air from the system, creating a vacuum throughout.



**Cooler**  
Fresh from the cow, the milk is about 30°C to 40°C (86°F to 101°F), but cold water running through the cooler reduces this to 20°C (68°F).

A typical bulk tank can hold 4.5 litres (1.2 gallons) of milk and is collected daily.



**Bulk tank**  
All of the milk is finally distributed into a large refrigerated tank, which keeps it below 6°C (42.8°F).



**Filter**  
The milk passes through a filter to remove any dirt or mud carried from the cow's udders.



**Milk pipeline**  
The milk is drawn through the cluster and along the milk pipeline because of the vacuum.

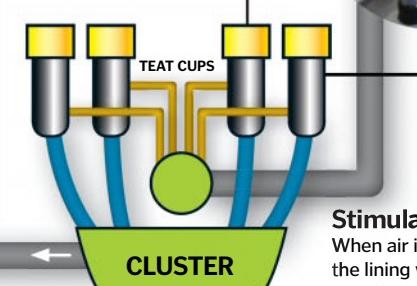


**Pulsator**  
Air is pulsated through the teat cups at a rate of about 60 times per minute.

Four teat cups attached to a cluster are used to milk the cows



**Milk flow**  
When exposed to the vacuum, the lining within the teat cup is released and the milk flows.



**Stimulation**  
When air is forced in, the lining within each cup closes around the teat to stimulate it.

# Feeding time

## The typical diet of a dairy cow

In addition to raising and milking the cows, the farmer also has to grow their food. Many farms have hundreds of acres of land for growing feed crops, and the most important of these for a dairy farm is grass. During the summer months, the cows feed themselves by grazing on fresh grass in the fields, but in the winter when they are kept indoors, they have to get their grass another way.

Twice a year, surplus grass is cut and placed in a large heap called a clamp. The clamp is then compressed to remove any air and covered so that the grass is left to pickle and become damp silage that can be stored for winter.

The tropical crop forage maize is also grown



The cows' food is mixed in a large machine called a forage wagon

during the warm summer months and harvested in the autumn. It is then chopped up to crush the corn kernels, making them easier for the cows to digest, and added to the grass silage.

Although they are a lot of work, these crops are relatively cheap to produce. They are also usually fertilised with the dung produced by the cows, creating a self-sustaining farming operation.

## What's for dinner?

### The main components of a cow's diet

#### Fodder beet

Closely related to sugar beet, this sweet-tasting root plant is rich in carbohydrates so acts as a great source of energy.



#### Maize

Forage maize is high in starch for extra energy and adds some bulk to the grass silage.

#### Protein pellets

Also known as cattle cakes, these supplements add protein, vitamins and minerals to the cow's diet.

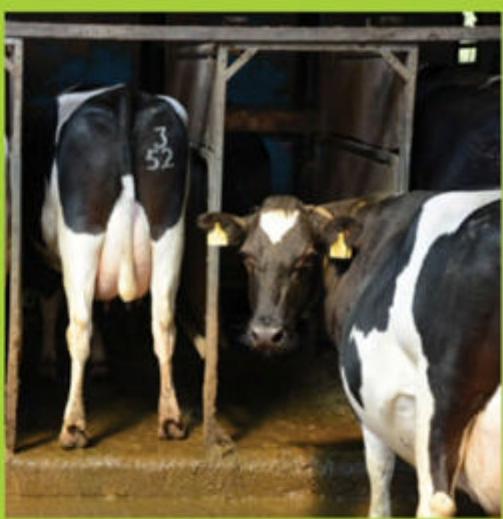
#### Grass

Grass is a cow's main source of food. It's packed with nutrients that help the cow produce better quality milk.

## Hi-tech feeding

When it comes to getting their daily dose of protein pellets, each cow receives their own tailor-made portion. This is controlled by an automatic feeding station, which uses antenna to recognise each cow based on signals received from a transponder strapped around its neck.

The transponder is also linked to the milking machine, and records the amount of milk the cow produces each day. The feeding station uses this data, plus information about when the cow last had a calf, to work out how many protein pellets it should receive to improve milk production. As well as making things easier for the farmer, this system is also useful for monitoring the cow's health. The weight of the food left in the trough after feeding is used to work out how much the cow has eaten. If they are not eating enough then the farmer is notified, as this could be a sign of poor health.



## Advertisorial

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# How a bottle is recycled

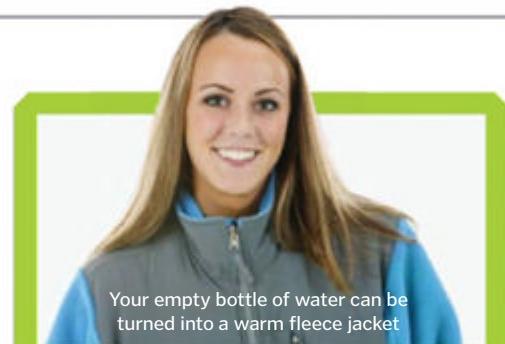
What happens when you put your plastic bottle in the recycling bin?

The average UK household throws away an estimated 500 plastic bottles every year, and a large percentage of them end up at landfill sites. Most plastic bottles are made from polyethylene terephthalate (PET) or high-density polyethylene (HDPE), both of which are degradable plastics. This means that when they are exposed to enough light, oxygen, heat or mechanical stress, they can break down into water, carbon dioxide, biomass and trace elements.

However, this process can take hundreds of years, and during that time the plastic is taking up

landfill space and can be potentially harmful to wildlife, particularly if it ends up in the sea. The best solution for disposing of plastic bottles is to recycle them into new ones.

As well as reducing the amount of waste going to landfill, this also helps to conserve the non-renewable fossil fuels needed to make the bottles from scratch and reduce the emissions of greenhouse gases normally created during this process. In fact, recycling one plastic bottle can save enough energy to power a 60-watt light bulb for three hours.



Your empty bottle of water can be turned into a warm fleece jacket

## Made from bottles

Recycled plastic bottles can be turned into all sorts of useful things, not just new plastic bottles. For example, the flakes made from melting plastic can be spun into a fine polyester fibre, which can be used to make fleece clothing, carpets and duvet filling. 25 recycled 500-millilitre (17.6-ounce) bottles can make one fleece jacket and five two-litre (0.44-gallon) bottles can be turned into 0.09 square metres (one square foot) of carpet. The durability of recycled plastic also makes it ideal for use in drainage pipes, scaffolding boards and fences and it's also a cheap material for making street furniture, signs and even bins. In fact, your recycling bin may be made from the contents you put into it. The stationery in your pencil case could be made from recycled bottles too, as the plastic flakes can be reshaped into rulers, pencil sharpeners and other items.

## The recycling journey

How your plastic bottle is reborn

### 1 Collection

Your empty plastic bottle is collected and taken to a recycling facility for sorting. If you have already separated the plastic bottles from the rest of your recycling they can be sent straight to a recycling plant.

**275,000 TONS**

Amount of plastic used in the UK per year

**500+ YEARS**

How long plastic can take to decompose

### 2 Separating

The recycling is hand-checked to remove any non-recyclable material. It is then loaded into a 'trommel', a large perforated spinning drum. Plastic bottles and cans are separated through the perforations, and then steel and aluminium cans are removed using magnets and electromagnetic technology.

### 3 Sorting

The bottles are then cleaned and sorted by type and colour using infrared beams. The infrared light is reflected off of the plastics in different ways, allowing a sensor to detect which is which. Precision jets of air then separate the different types.

### 4 Shredding and melting

Next the bottles are shredded by a machine and the shreds washed again to remove any impurities, including remnants of paper labels or the bottle's original contents. They may also be decontaminated further using a chemical solution. The shreds of plastic are then dried and melted down.

### 5 Flaking

The melted plastic is reformed into flakes or pellets as it cools. These can then be melted down again and used to make new products. For example, the melted plastic can be reshaped into new plastic bottles, ready to be filled with a product.





# Life of a monarch butterfly

The butterfly king makes a spectacular migration, guided by instinct and an internal compass

**T**he monarch is one of the most recognisable and beloved butterflies in the world. It is also one of the most remarkable. Each year, anywhere between 60 million and 1 billion of them undertake an incredible winter migration from the chilly regions of southern Canada and northern USA to southern California and the forests of western central Mexico – a distance of up to 4,828 kilometres (3,000 miles).

Monarchs have a wingspan of about 10.4 centimetres (four inches), and are identified by their striking black, white and orange colouring. Males and females are almost identical apart from a dark spot on the hind wing of the male – a scent gland that produces chemicals to attract females. As well as being undeniably beautiful, their bright colouring warns predators that they are foul tasting and poisonous.

The butterflies actually develop their poisonous quality as caterpillars. Female monarchs lay their eggs on the toxic milkweed plant, and the caterpillars feed exclusively on this. Its glycoside toxins are harmless to the monarch, but poisonous to the monarch's predators. By munching milkweed, the caterpillars develop a reservoir of toxins in their bodies, which persist in their system beyond metamorphosis and make them an ill-advised meal.

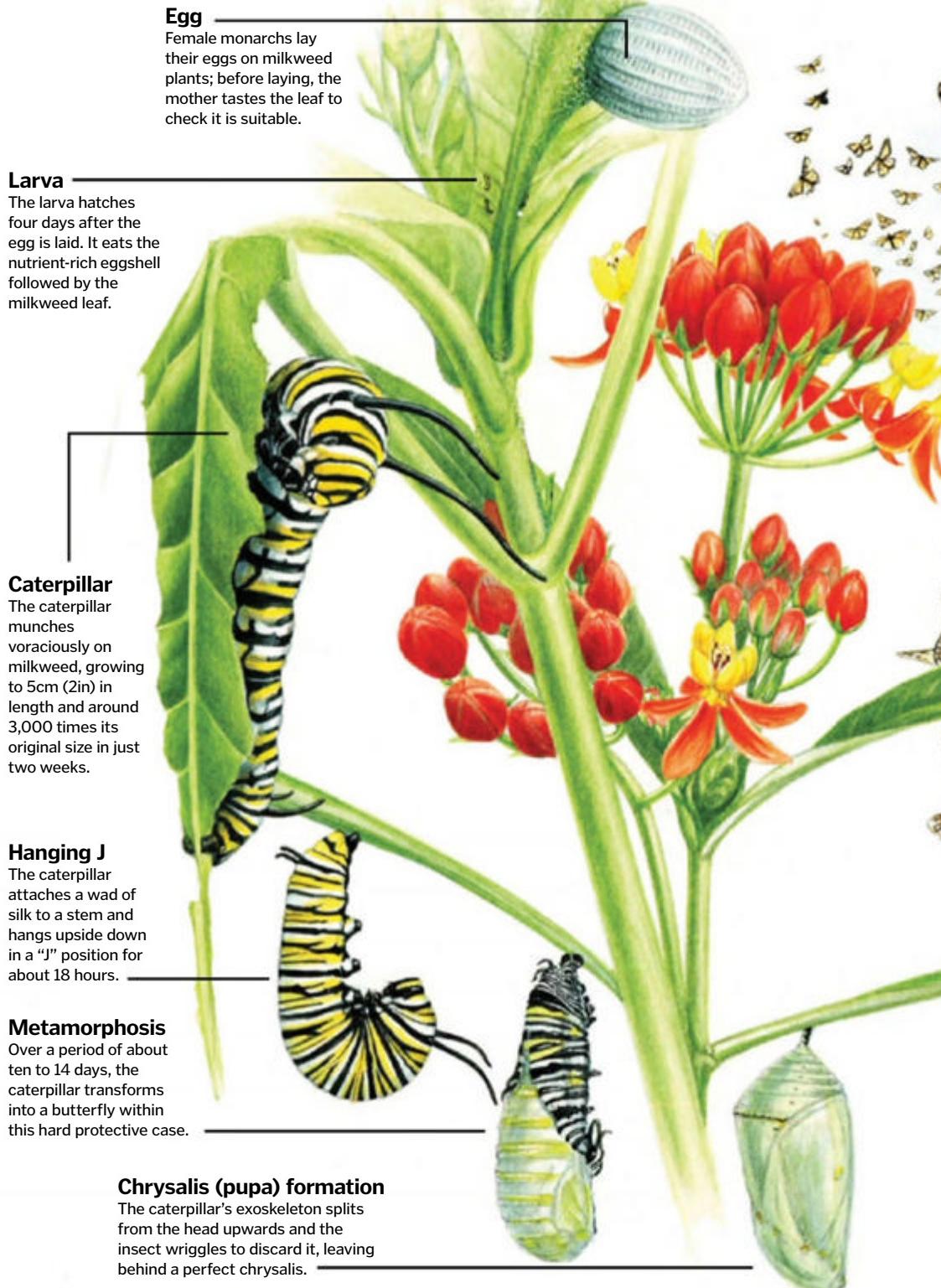
Most monarchs don't live longer than about five weeks. About three to five generations are born between early spring and the end of summer, but the generation that emerges from their chrysalises at the start of autumn is different. This is the "over-wintering" generation, and it's their job to fly south, away from the freezing North American winters, and ensure the survival of the species.

The migration is astounding, not only in terms of the distances the butterflies cover, but also for the fact that they instinctively know the route, despite never having made the journey before. Their arrival in Mexico usually coincides with Día de Muertos (Day of the Dead), one of Mexico's most important holidays. According to local legend, the arriving monarchs are believed to be the souls of the deceased returning to Earth.

Over-wintering monarchs live for up to eight months. They embark on the northward journey in early spring, mating on the wing and laying their eggs on milkweed plants in the southern United States. Their offspring will complete the journey north, before the whole cycle begins again. ☀

## Metamorphosis

The transformation from caterpillar to butterfly



**"Between 60 million and 1 billion monarchs undertake an incredible winter migration"**

**Take off!**

The monarch finally spreads its wings and takes flight, ready to begin the cycle all over again.



**Flight preparation**

A newly emerged butterfly waits about an hour for its wings to dry completely and become fully airworthy.

**Emergence**

The adult monarch pushes its way out, grabbing onto the exoskeleton; within minutes, its tiny folded wings grow to full size.

**Final stages**

The green pupa becomes transparent one day before the adult is ready to emerge.

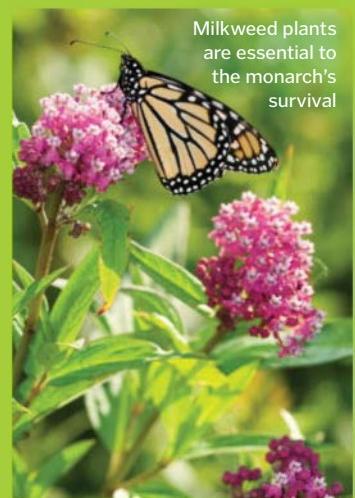


## Fluttering on the brink

Revered or not, the monarch is under threat. Populations have fallen drastically since the Nineties due to environmental degradation and human agricultural practices.

In Mexico, habitat loss from illegal logging, plus a string of natural disasters have reduced the availability of suitable overwintering grounds. In the US, herbicides used by farmers have decimated the monarchs' vital host milkweed plants.

Experts are also concerned about how global warming will affect rainfall patterns and alter the timing of the migration. Monarchs can't fly unless their body temperature is at least 30 degrees Celsius (86 degrees Fahrenheit), so cold snaps in Mexico – one of the predicted effects of climate change – could spell disaster for the species. According to the US Fish and Wildlife Service: "Unless we act now to help the monarch, this amazing animal could disappear in our lifetime."



Milkweed plants are essential to the monarch's survival



# The fearless honey badger

Hyenas, lions and snakes know better than to mess with the ruthless honey badger!

**W**hen you think of badgers, you probably imagine shy, snuffling woodland creatures with pretty, striped faces. Brace yourself, because the honey badger – despite its sweet name – is a whole different mouthful of teeth. In fact, it holds the official Guinness Book of World Records title for most fearless animal in the world!

Despite their name, honey badgers actually have more in common with weasels than they do with the other badger species. Around one metre (3.3 feet) in length and 30 centimetres (12 inches) tall, their bodies are squat, stocky and incredibly strong, and they move with a self-assured trot. They're nocturnal and generally solitary, and a large brain-to-body size ratio makes them master problem solvers.

Honey badgers are also ferocious fighters, all rattling snarls and vicious lunges. They don't

think twice about giving attitude to hyenas – animals five times their weight, with jaws more powerful than a lion's – and are reported to go for the scrotum. One account even tells of a trio of honey badgers teaming up to chase a group of seven lions from their kill.

It may sound like the honey badger has a death wish, but this crazy little critter has every reason to be so bold. Virtually no predator can get the better of it, thanks to its secret weapon: its rubbery skin. At over half a centimetre (0.2 inches) thick, it is almost impenetrable to sharp objects, including spears, scorpion stings, and porcupine spines. Because the skin hangs loose around its muscular frame, a caught honey badger is able to twist right around and sink its vicious teeth and claws into its attacker's face. It can take a fully-grown leopard an hour to kill one of these tenacious little beasts! ⚡



## What's on the menu?

Literally everything. Honey badgers are eating machines with high metabolisms, meaning they're constantly on the lookout for food. As their name suggests, they have a penchant for honeycomb; in particular the protein-rich bee larvae, which they will climb trees and shrug off hundreds of stings to secure.

As much as half of a honey badger's diet is made up of venomous snakes like puff adders. Even if they get bitten in battle, the relentless attackers are seemingly resistant to snake venom and apparently able to sleep off its effects in just a short time.

They also enjoy eating rodents, reptiles, birds, insects, small mammals, carrion and trash, and will just as soon scavenge as hunt. Where they cross paths with human residences, honey badgers will rifle through bins and ransack homes and kitchens, earning them the title 'masters of mayhem'.

Asperatus clouds have been spotted in England, France, Norway and the USA

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# Asperatus clouds

Find out what causes the world's newest cloud formation

**T**he last time a new type of cloud was officially recognised by the UN's World Meteorological Organization was in 1951, but these choppy seas in the sky could be next. After being unable to identify the clouds from photos sent in by sky watchers all over the world, the Cloud Appreciation Society has proposed that they should be officially

classified as asperatus clouds, inspired by the Latin word for 'roughened'. For this to happen, the cause of the cloud has to be identified first. Although their formation is not yet entirely understood, some experts believe that they form under the same conditions as mammatus clouds, which look as though they have a series of pouches hanging below them. These occur

when ice crystals in the clouds sink, but are too large to evaporate in the air below. To form an asperatus cloud, strong winds then shear the underside of the mammatus cloud to form undulating waves instead of pouches. If they are classified, the clouds will be included in the International Cloud Atlas, which has not been published since 1975. 

# Frost flowers

How do these stunning ice blooms grow?

**T**hey may look like strange plants or even sea creatures, but these beautiful formations are actually intricate ice sculptures that grow naturally on thin ice. They have been spotted on frozen lakes, ponds and sea ice, but require very specific conditions to form. The air above the surface of the ice must be still, dry and about 20 degrees Celsius (68 degrees Fahrenheit) colder than the temperature of the ice itself. This makes it possible for the surface ice to sublime, meaning that it changes directly from a solid to a gas, skipping the liquid stage in-between. As this water vapour hits the cold air above the ice, it condenses to form ice crystals that attach to imperfections or cracks on the surface. With very little wind around, the crystals do not blow away, and are left to grow naturally into stunning frost flowers. As they grow, the flowers also draw up more water from the ice below, and this often contains microorganisms. In fact, the density of bacteria found in many frost flowers means that each one is its own temporary ecosystem. 

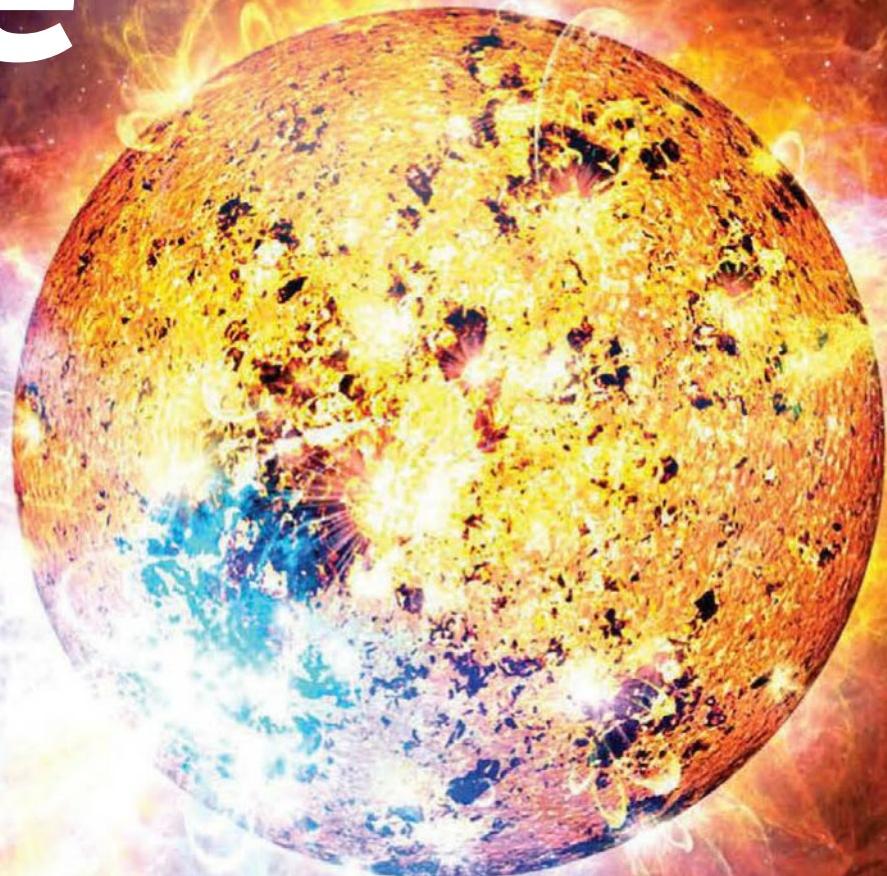
Frost flowers are typically found in the Arctic and Antarctic





# Zombie stars

Plus six other strange celestial wonders explained



Flare stars are usually red dwarfs, which are cooler and smaller than our Sun

## 1 Flare stars

If you're looking for a star that's unpredictable, then the flare star is it. With their dramatic bursts of brightness, flare stars often come in the form of dim red dwarfs, which are small and relatively cool stars compared to our Sun.

They're not too dissimilar to our star, though – the material that erupts from their surfaces is similar to how solar flares storm from the Sun's surface – and it's all down to magnetic reconnection in the stars' atmospheres.

Magnetic reconnection is when magnetic fields are rearranged, causing high

temperatures and particles to race away at high speeds. From Earth, flare stars usually appear quite faint to us despite turning up the brightness. In fact, in order to be able to see one, you would need your own space telescope.

In April 2014, NASA's Swift satellite observed a record-breaking sequence of eruptions from a nearby red dwarf star at a distance of roughly 60 light years. The blasts were so bright that they were measured to be as much as 10,000 times more powerful than the biggest solar flare ever recorded.



Flare stars play host to unpredictable bursts in brightness



## 2 Blue stragglers

The blue stragglers are a bit of a contradiction. These stars, which burn hot and shine blue, appear to be quite young, yet they reside in open or globular star clusters – gatherings of ancient stars that are usually the same age because they all formed and grew up together.

They're called blue stragglers because in terms of their evolution, they appear to be lagging

behind their neighbours. Just how they come to exist is still a bit of a mystery and two possible ways are shown below. According to astronomers, the most obvious explanation is that these young stars must have been made from the merger of two older, low-mass stars within the dense confines of the cluster, making a more massive star that's rejuvenated and appears much younger.

## The collision model

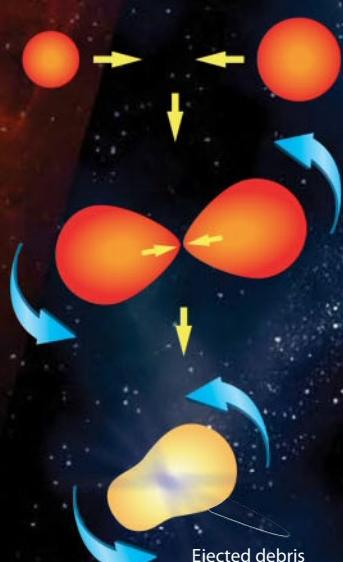
### 1 Collision course

Two low-mass stars head toward each other for a head-on collision.



### 2 Stellar tango

As the two stars enter into each other's gravitational influence, they begin rotating around each other before spinning into one another.



### 3 A reborn star

The new merged star appears from the debris of the collision and shines hot and blue.



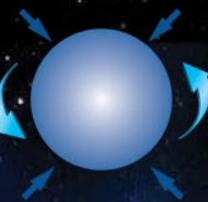
### 4 Swollen star

The evolution of the star is not over yet. The extra heating causes the star to swell and expand, turning red as its rotation slows.



### 5 Contraction

As the interior of the star settles down, it contracts again, turning blue once more.



## The slow coalescence model

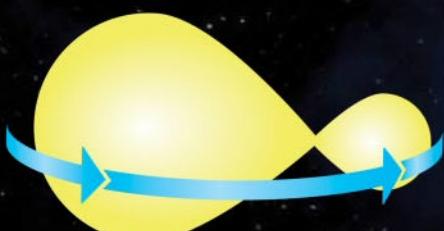
### 1 Close companions

Sometimes stars come in close pairs – so close that they are actually touching and begin to transfer material.



### 2 Vampire star

The larger star's stronger gravity wins out, and begins cannibalising the smaller partner. As it does so, the larger star spins up.



### 3 Fast spinner

The larger star grows more massive, hotter and bluer, and spins at least 75 times faster than our Sun.



## 3 Zombie stars

We know the Type Ia supernova as the explosive death of a white dwarf star, completely blown to smithereens. There can be survivors in such a catastrophe, however. These beat the odds in what is known as a Type Iax supernova eruption. Occasionally, the supernova explosion is unusually weak (relatively speaking), allowing a portion of the original white dwarf star to survive. In 2014, astronomers studying archived Hubble images identified one such battered and bruised supernova survivor. These white dwarf remnants appear to come back to life as they explode, earning them the nickname of zombie stars.

If a supernova explosion is relatively weak, bits of a white dwarf star can survive

**Crusty star**

A strange quark star would form inside a neutron star, so it is expected to have a thick crust of neutrons surrounding it.

Tobias Roetsch

**Explosive stars**

A handful of supernovas have been seen to have exploded brighter than any others, and some scientists think they signal the birth of quark stars.

**Small stars**

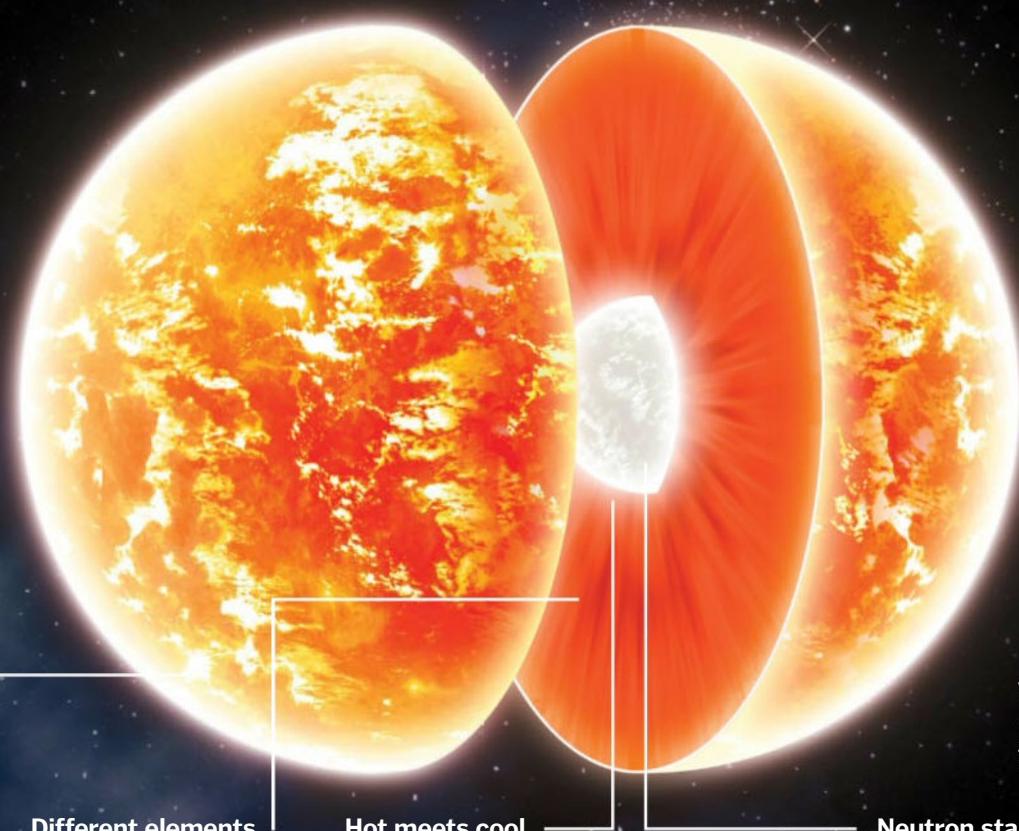
Quark stars would be very small, less than 10km (6.2mi) across.



# 5 Hybrid stars

Akin to a Russian doll, a hybrid star is actually quite bizarre – especially since they exist as one star encased inside the shell of another – simply because the larger star has gobbed up the smaller one.

It was physicist Kip Thorne and astronomer Anna Zytkow who proposed that such a star existed back in the Seventies, but it wasn't until 40 years of searching that a hybrid star – also known as a Thorne-Zytkow object – was uncovered. To look at, a hybrid star seems like your standard red supergiant, similar to Betelgeuse in the constellation of Orion. But it's the chemical fingerprints they leave, measured by analysing the red supergiant's starlight, that give a neutron star away.



## Inside a hybrid

Thorne-Zytkow objects are bizarre hybrids, so we get two stars for the price of one

**The red giant**

The outside of the star is the red giant, which is the puffed-up transformation of a Sun-like star near the end of its life.

**Different elements**

The difference in temperature of the two stars might result to rather unusual stellar chemistry, with different isotopes of elements being created.

**Hot meets cool**

The neutron star is very hot, over 1bn°C (1.8bn°F), while the red giant is just a few thousand degrees hot.

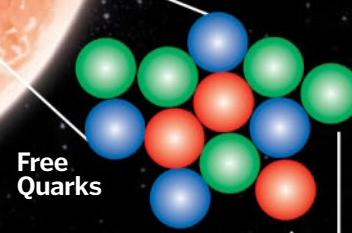
**Neutron star**

At the core of the star is the neutron star. In this diagram its size has been exaggerated, as neutron stars are only 10-20km (6.2-12.4mi) across, but incredibly dense.

# 4 Quark stars

This type of star is one of the most exotic of all – so exotic that we're yet to even find one.

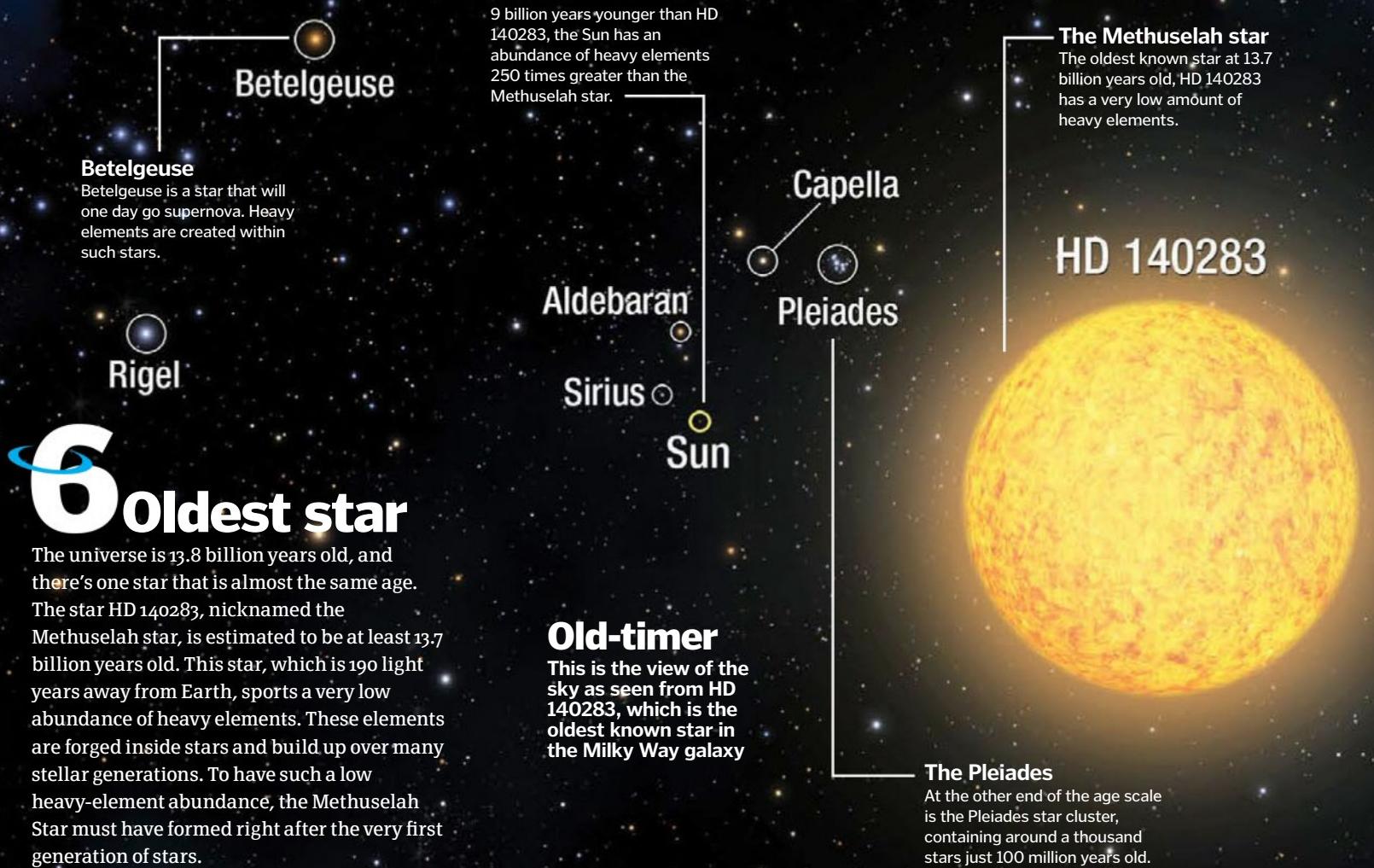
Quarks are fundamental particles – they make up the protons and neutrons we find in the nuclei of atoms. So why would we find an entire star made not of atoms, nor protons and neutrons, but just quarks? When massive stars explode, their cores are compressed down to the point that their atoms are crushed so that protons merge with electrons to form a neutron star. The theory behind quark stars is, if the pressure is great, it can even squeeze the neutrons apart into their component quarks.



- Up Quarks
- Down Quarks
- Strange Quarks

**Up and down**

The most common types of quark are described as 'up' and 'down' and make up protons and neutrons.



## 6 Oldest star

The universe is 13.8 billion years old, and there's one star that is almost the same age. The star HD 140283, nicknamed the Methuselah star, is estimated to be at least 13.7 billion years old. This star, which is 190 light years away from Earth, sports a very low abundance of heavy elements. These elements are forged inside stars and build up over many stellar generations. To have such a low heavy-element abundance, the Methuselah star must have formed right after the very first generation of stars.

## Whirling dervish

How Vega loses its spherical shape because it's too quick

### Debris disc

Vega is a relatively young star, which is why it still has its debris disc, and younger stars tend to spin faster.



### A quick spin

Vega takes just 12.5 hours to complete one revolution. In comparison, our Sun takes about a month.

### Dizzying rotation

Fast rotators like Vega and Regulus spin at hundreds of thousands of kilometres per hour.

### Temperature

Vega's bulge means the surface temperature varies across the star, with the hottest temperatures found at the star's poles.

## 7 Egg-shaped star

You haven't really met a strange-looking star until you've come across an egg-shaped one. Regulus, which you can see from Earth in the constellation of Leo, is one such stellar abnormality.

Stars like to spin, with some moving faster than others. Our Sun is able to hit speeds of 7,242 kilometres (4,500 miles) per hour. However, the giant star Regulus, which is at least three times bigger than the Sun, clocks a velocity of almost 1.13 million kilometres (700,000 miles) per hour despite its sheer size. Another speedy spinner is Vega, the bright star in the constellation of Lyra, which spins at a rate of 986,400 kilometres (613,000 miles) per hour. Being fast movers means these stars lose their spherical shape as centrifugal forces cause their equators to bulge outward and the stars appear egg-shaped instead.



# Hubble's 25<sup>th</sup> anniversary

Celebrating a quarter-century of the world's most famous telescope



Every 97 minutes, the Hubble Space Telescope completes one orbit of our planet, capturing incredible images of the universe as it goes. From its position 552km (343 miles) above Earth, it can avoid the atmospheric distortion that plagues ground-based telescopes and record more wavelengths of light to examine celestial bodies in spectacular detail.

It collects this light using a very large primary mirror. It then reflects it onto a secondary mirror, which focuses it onto the telescope's science instruments, including a wide field camera. However, when Hubble first launched in April 1990,

a tiny flaw in the primary mirror meant that the first images it produced were blurry. Light that bounced off the centre of the mirror focused in a different place to the light bouncing off the edge, distorting the final image. In 1993, a team of astronauts travelled to Hubble to fix it in orbit, adding a series of small mirrors that could intercept the light reflecting off of the primary mirror and correct the flaw. The mission was successful and Hubble has been producing sharp, detailed images ever since.

More than 100 terabytes of data has been generated by Hubble, and more than 10,000

scientific articles have been published based on its findings. It has also helped astronomers discover dark energy, find out how galaxies form and determine that the universe is approximately 13.7 billion years old, not somewhere between 10 to 20 billion as previously thought.

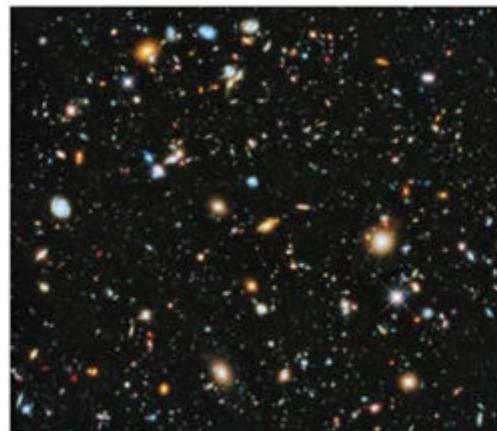
Soon though, Hubble's story will come to an end. As its components slowly degrade, it will eventually stop working, and a robotic spacecraft will be sent to guide it back down to Earth. It will then be time for Hubble's successor, the James Webb Telescope to take over, with a launch scheduled for 2018.

## Hubble's greatest hits



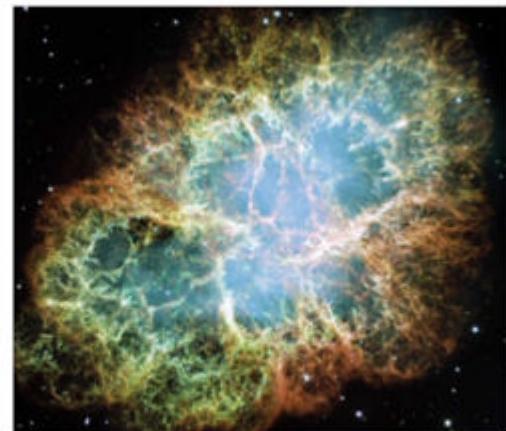
**Pillars of creation**

Perhaps the most iconic Hubble image, it shows three giant columns of cold gas, dubbed the pillars of creation, glowing under the light from a cluster of young stars in the Eagle Nebula.



**Deep space**

This composite of images taken between 2003 and 2012 contains approximately 10,000 galaxies, and enables astronomers to look back in time to within a few hundred years of the big bang.



**Crab nebula**

The result of a supernova first noted by Earth-bound astronomers in 1054, the Crab Nebula rotates 30 times a second and has a neutron star as massive as the Sun at its centre.



**Andromeda galaxy**

The largest Hubble image ever assembled shows our galactic next-door neighbour, the Andromeda Galaxy. Although over 2 million light years away, the image is sharp enough to show over 100 million individual stars.

**DID YOU KNOW?** Hubble transmits 120 gigabytes of data weekly, enough to fill a 1,097 metre [3,600 foot] long shelf of books.



**"More than 10,000 scientific articles have been published based on Hubble's findings"**

#### Learn more

To find out more about Hubble's incredible journey head over to [www.hubblesite.org](http://www.hubblesite.org). Here you can learn about its incredible discoveries, see more stunning images of the universe and even learn how to build your own Hubble model.

## A troubled mission

We spoke to BAFTA nominated filmmaker Christopher Riley about his time with the Hubble team when making the documentary *Hubble's Cosmic Journey*

### What did you learn from talking to the Hubble team?

The thing that surprised me the most was that all these decades on, the engineering team, particularly those who made the mirror that had the flaw in it, still had this terrible burden of blame that had been poured on them. It took me quite some time to persuade them to take part in the film at all. They were so ahead of their time engineering-wise that the digital camera technology on the telescope, which was refitted every few years during space shuttle missions, only caught up in 2009 and they made this mirror back in the Seventies. Yet despite that they were still thought to be the problem rather than something to be celebrated because of the initial problems with the mirror.

### What excites you the most about Hubble?

For me, the most powerful images are the deep field images that started to be taken in the mid Nineties. The team basically point it at a tiny speck of seemingly empty sky and they do this repeatedly over the course of years. The great thing about Hubble is that they can point it at exactly the same bit of sky. It's the equivalent of being on top of the Washington Monument and pointing a laser at a coin on top of the Empire State Building that's 250 miles away, and holding the laser steady on the face on the coin. So when they point it at these tiny bits of space, they can repeat the same experiment and collect more and more light. They then build this up digitally until they've got these fabulous

exposures of deep parts of the cosmos that reveal our universe as it was over 13 billion years ago.

### What questions do you hope Hubble will help us answer in the future?

I think there's a good five years of life left in Hubble before it needs to be retired. It still strives to do deep surveys of the sky. When I was filming at mission control, it was tracking down new target objects for NASA's New Horizons mission, which is on its way to Pluto. It will pass Pluto this summer and then head out to one of the other icy objects beyond in the Kuiper belt. Hubble was trying to track down an object for this mission to divert to. These objects are over 4 billion miles away, so they are pretty difficult to spot. But thanks to



Hubble's power, even 25 years after it was launched, it can still contribute to modern day missions.



# NASA's twins study explained

How one set of identical twins and a yearlong journey in space will help NASA prepare for a mission to Mars

**O**n 27 March 2015, astronaut Scott Kelly voluntarily voyaged into space on a unique one-year mission for NASA. His identical twin brother Mark, a retired astronaut, is also integral to the study, although his feet will remain firmly on planet Earth for the duration of it. This unprecedented experiment offers scientists a rare opportunity to study the effects long-term spaceflight has on the human body, which is vital if NASA hopes to one day send astronauts on a mission to Mars.

The fact that the brothers are identical twins is crucial to the investigation, as they share virtually the same DNA. This means scientists will be able to closely compare any physiological and mental changes that occur between them during the experiment. Prior to Scott's arrival at

the International Space Station, NASA researchers collected genomic, physiological, molecular and other data from each twin, something that will continue to be reviewed and compared both during the mission and after Scott has returned to Earth.

Biological samples including blood and saliva are expected to uncover more evidence on the physiological effects of spaceflight, as the investigation will look closely at how environmental stressors, such as microgravity, radiation and confinement, affect the muscles, heart and brain. Behavioural changes will also be compared and documented, in order to better understand how the likes of reasoning, perception and decision-making are also affected by long-term space missions.



Astronaut Scott Kelly (right) along with his brother, former astronaut Mark Kelly (left)

The Soyuz TMA-16M spacecraft launched Scott Kelly and the rest of the crew to the ISS



## Physiological effects of space

Space travel can have a dramatic physiological effect on the human body. Reduced gravity, even over a short period of time, can be detrimental. On Earth, our bodies are constantly working against gravity and this helps to keep our muscles and bones strong, so without it they will effectively start to weaken. Bone and muscle loss is a common side effect of microgravity, as it makes physical activities less demanding. The reduced workload on your muscles and bones makes your body think those cells are no longer required, so over time they will waste away.

Astronauts also grow a few centimetres in height while in space because the spine stretches and lengthens without gravity pushing it down. This in turn can lead to back aches. Astronauts typically suffer from headaches, nausea and swelling while their bodies adapt to their new environment.



Microgravity can have an adverse affect on the human body and cause astronauts to suffer from bone and muscle loss in space

## Science of identical twins

There are two different types of twins; identical, known as monozygotic, which occurs when one sperm fertilises one egg; and nonidentical, or dizygotic, which is when two separate sperm fertilise two separate eggs. Identical twins are the less common of the two, as once the egg has been fertilised the cell will split in two, which as result means both embryos share the same DNA code.

Your DNA is responsible for making you who you are, which is why identical twins are the same sex and look so much alike. Slight differences in appearance and behaviour are a result of environmental factors, and as changes to our genes can still occur in the womb, it's possible (although very rare) for one twin to develop a genetic condition while the other does not.



Identical twins share the same DNA code as they come from the same fertilised egg

# Antstronauts

Learn how a microgravity study of ants could lead to better robots

Several hundred ants are currently in orbit on the International Space Station, in an experiment to see how they adapt to microgravity environments. The way ant colonies work is fascinating. They don't have a central control; no single ant can force another to do something. Instead, they use information gathered locally to assess situations, which means the behaviour of the colony depends on the local cues each ant produces. Colonies send out worker ants to search and assess new areas. This can help them find food, map foreign terrain and identify potential threats.

By studying the ways ants assess an alien environment, scientists believe they will be able to develop better search algorithms for robots. They want to create autonomous search robots that do not need a central control, much like ant colonies. These would then be more effective at tasks such as finding survivors immediately after a disaster takes place. This research could also impact mobile phone networks, helping to solve problems of interference. ⚀



# How robots keep astronauts company

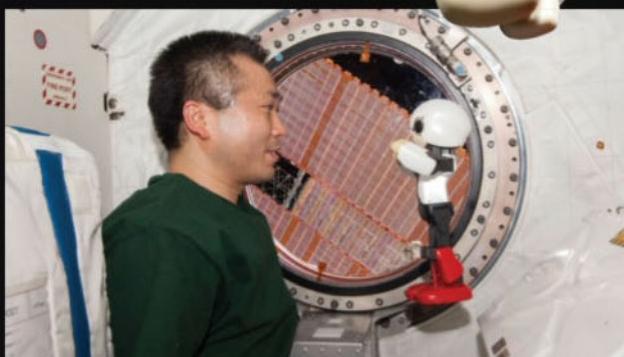
Meet Kirobo, the Japanese robot living on the ISS

Feelings of loneliness are often hard to avoid when you're in space. Astronauts who stay on the International Space Station (ISS) for extended periods often struggle with this. Sometimes, their psychological issues can be harder to deal with than living in microgravity or sleeping upright.

To combat this, Japanese scientists designed a robot with the aim of providing psychological support. It was named Kirobo, which is derived from the Japanese word for hope ("kibo") and robot. Kirobo stands 34 centimetres (13.4 inches) tall and weighs one kilogram (2.2 pounds). It has a clever voice-recognition system and can produce its own sentences with the help of an advanced language-processing system, and its own built-in voice synthesis software.

These innovative systems were actually designed by Toyota, which plans to use the

technology to develop other robots' conversational abilities. The Kirobo experiment also aimed to see how humans and robots might live alongside each other during longer space missions, which may take place in the future. Kirobo has now returned to Earth after an 18-month stay aboard the ISS. ⚀



© Corbis/NASA/Toyota

# BRAIN DUMP

Because enquiring minds need to know...

## MEET THE EXPERTS

Who's answering your questions this month?

### Luis Villazon



Luis has a degree in zoology from Oxford Uni and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

### Laura Mears



Laura studied biomedical science at King's College London and has a masters from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

### Alexandra Cheung



Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

### Sarah Banks



Sarah has a degree in English and has been a writer and editor for more than a decade.

Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

### Shanna Freeman



Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

## Want answers?

Send your questions to...



How It Works magazine



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Riding the Wall of Death requires a good understanding of physics and a lot of bravery

## How do motorcyclists ride the Wall of Death without falling down?

### Colin Noble

The Wall of Death – also known as the motordrome or silodrome – is a barrel-shaped cylinder, usually made out of wood. Motorcyclists perform stunts while riding on the vertical wall. The Wall of Death is a popular travelling carnival act dating from the early-20th century, but there are just a few left today. The motorcyclist starts at the bottom with the crowd looking down into the drum. After ascending a ramp to gain speed, they then begin circling the vertical

wall, held in place by centripetal force. There are three forces working on the cyclist: gravity, the wall and friction. The cyclist must maintain a constant speed to keep the motorcycle's direction of motion constantly changing. They must also lean up at an angle (with respect to the wall) while riding to keep the bike's torque at zero. This impressive feat occasionally results in accidents if the cyclist gets too close to the top of the wall or fails to maintain the speed or angle necessary to stay up. SF



The closer you sit, the higher the screen resolution needs to be

## Are our eyes able to fully appreciate 4K TVs?

### Estelle Firth

Yes. The maximum visual acuity of the eye is 0.3 arc-minutes. That means that under good lighting conditions, you can distinguish two dots that are 0.005 degrees apart. 4K TV resolution is 3,840 x 2,160 pixels, so to be able to distinguish individual pixels, the screen must cover at least 19.2 degrees in your field of vision. For a 48-inch screen, that happens when the screen is just over three metres (9.8 feet) away from you. As long as you sit no further than that from the screen, and your vision is sharp, you will be able to appreciate 4K resolution. LV



## Why do reflections in mirrors appear reversed?

Lauren Craft

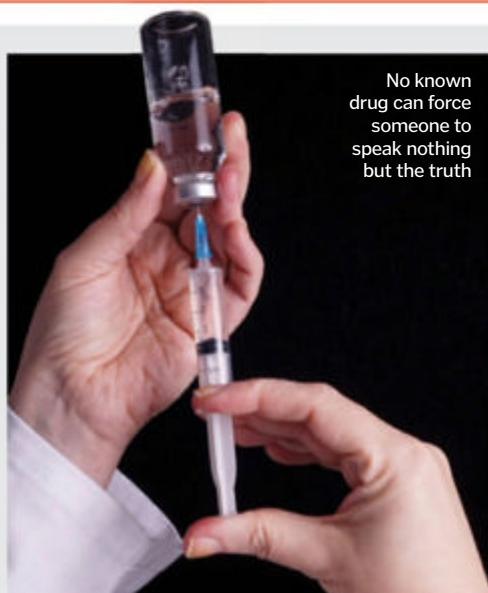
■ Mirrors appear to reverse things from left to right because of our perceptions. Our bodies are roughly symmetrical, so the reflection of your left hand looks just like your right hand. For this reason, we tend to assume that mirrors reverse left and right. But if you hold up an asymmetric object in front of a mirror, for example a saucepan, left and right are not reversed. The right-hand side of the saucepan (for instance the handle) is still on the right, and the left-hand side is reflected on the left. Instead, a mirror inverts front and back. AC



## How does truth serum work?

Mandy Jones

■ Various drugs have been used as 'truth serums' although none can reliably make their victims speak the truth. Many so-called truth serums are barbiturates, such as sodium thiopental, originally used as anaesthetics or sedatives. Similar to alcohol, they depress the central nervous system and impair judgement and cognitive function. Doctors observed that these drugs reduced inhibitions in patients, causing them to talk more freely. One theory is that by disrupting brain function, such drugs might make it more difficult for a suspect to concentrate enough to lie convincingly. But these drugs also tend to make people extremely suggestible and downright incoherent, meaning they are just as likely to say whatever their interrogator wants to hear, or to babble complete nonsense, as to tell the truth. In most countries, confessions extracted from suspects under the influence of drugs are therefore inadmissible in court. AC



## Can opera singers shatter glass?

Freddie Stevens

■ It is possible for an opera singer to shatter glass; it's just not very likely! All objects have a frequency at which that object vibrates. Sound waves from the singer's voice vibrate air molecules surrounding the glass, causing the glass itself to vibrate. This is known as resonance. The glass would need to have microscopic defects big enough to buckle under the pressure in order for the glass to actually shatter, though. The chances of finding such a glass are slim, particularly as the fractures cannot be seen by the naked eye. Furthermore, the note must match the glass's resonant frequency. It has happened, though! SB

## FASCINATING FACTS

### The human body is extremely resilient

The human body can survive without several of our internal organs, including the appendix, the tonsils, one kidney, one lung, the stomach, the colon, the gallbladder and the spleen.

Other animals use their appendix to aid with digestion of plant material, but in humans this organ is not needed



## What will happen when the Sun dies?

Mick Barrow

■ As the Sun dies, it will swell before exploding into a planetary nebula. In the coming few billion years, the Sun will gradually run out of hydrogen fuel and begin to fuse heavier elements. Its core will become denser while its outer layers grow hotter, expanding outward and evaporating all of Earth's water. Eventually the Sun will be a hundred times bigger than it is now, engulfing Mercury, Venus and possibly Earth. When it eventually runs out of fuel, it will eject its material outward in an expanding shell of gas, leaving behind a superdense but dim white dwarf star. AC



The Moon seen during the daytime over Colorado National Monument

## Why can we see the Moon in the daytime?

**Ruby Perkins**

■ The Moon is the second-brightest object in the sky and incredibly reflective of the Sun's rays. This means the reflected light can penetrate the scattered blue light of the sky. Though it may seem that the Sun rises in the east while the Moon sets in the west, the Sun and the Moon are only opposite each other in the sky when the Moon is at its full stage. In theory, the Moon is almost always visible in daytime, except when it's too close to the Sun (during a new moon) or too far away (during a full moon). **SF**



Charging your phone every night doesn't damage the battery at all

## Does charging your phone overnight kill the battery?

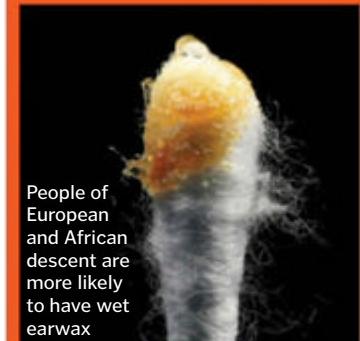
**Jordan Knight**

No. Overnight charging is actually the scenario phones are designed for. The charging circuit in your phone will cut out when the battery reaches maximum capacity. So you can't overcharge your phone, no matter how long you leave it plugged in. If you never unplug your phone from the wall, you will eventually lose battery capacity, though. That's because lithium batteries slowly degrade if they are held at maximum charge for long periods. After an entire year at full charge, a battery will lose 20 per cent of its maximum capacity, compared with just four per cent after a year at half charge. **LV**

## FASCINATING FACTS

### Earwax is protective

The medical term for earwax is cerumen, and it's produced by glands in the outer ear canal of mammals. Cerumen protects ears from foreign material such as insects and bacteria, and it also lubricates the skin of the ear canal.



People of European and African descent are more likely to have wet earwax

### The longest straight road is in Saudi Arabia

The longest straight road on the planet forms part of Saudi Arabia's Highway 10. Stretching across 261 kilometres (162 miles), it connects the town of Haradh to the border with the UAE.



Highway 10 stretches across the Saudi Arabian desert

### Excuse our French, but...

This phrase originates from the 19th century when English people used to drop French words into speech and say "excuse my French" if the listener seemed to not understand. The phrase was then adopted when people used unpleasant language.

French slang has long been popular in English





Opening your mouth when shocked is a fight-or-flight response that enables more oxygen to be inhaled

## Why do we open our mouths when shocked?

**Phillip Whitehouse**

■ Opening our mouths in shock or disbelief is considered to be an evolutionary response. Shock is related to fear. When we experience fear, our bodies will try to deal with whatever is frightening us by practising the fight-or-flight response. Whether the body decides to fight against the situation or fly away from it, it requires more oxygen in order to prepare the muscles to do one or the other. Opening our mouths in shock mimics taking a deep breath and therefore enabling more oxygen to be inhaled to deal with the situation. **SB**

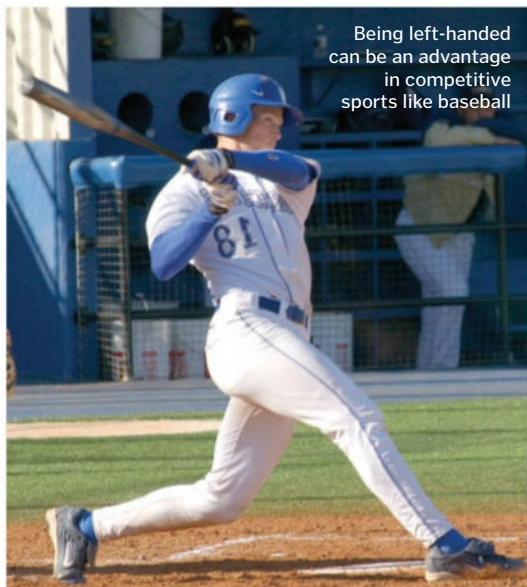
## How do we measure the distance to galaxies?

**Jeremy Windsor**

■ Astronomers estimate the distances to far-away galaxies by measuring the brightness of their stars. The easiest way of doing this is to find a special type of star called a Cepheid variable, whose brightness varies over time. US astronomer Henrietta Leavitt discovered over 100 years ago that the period of these fluctuations relates to Cepheid variable stars' true brightness. By comparing the star's true brightness to how bright it appears from Earth, its distance can then be calculated. Edwin Hubble used this method in 1923 to make the first accurate measurements of how far away the Andromeda galaxy is. **AC**



Cepheid variable stars are used to estimate distances to galaxies millions of light years away



Being left-handed can be an advantage in competitive sports like baseball

## Why are some people left-handed?

**Andrea Owen**

■ Around ten per cent of the general population is left handed, and according to archaeological evidence, this proportion has remained the same for around 5,000 years. A mathematical model developed by Northwestern University has a possible explanation.

Humans are a competitive species, and historically we fought hand-to-hand to settle disputes. In direct competition, left-handers have the advantage because their stance is unusual, and in one-on-one sports like fencing and baseball, there are many more left-handed athletes than you might expect.

If this were the only affecting factor, the numbers of left and right-handed people would eventually even out. However, even more important to humans than competition is co-operation. As a social species, one of our defining characteristics is the use of tools.

Left-handed people are at a disadvantage when using tools designed for right-handed people, and in golf, a sport where there is no direct competition and a heavy reliance of specialist tools, left-handers are under-represented. This balance between the advantage of novelty in competition and the disadvantage of difference in co-operation is thought to be the reason that some of the population is left-handed. **LM**

## Why do breaking waves look white?

**Geoff Strickland**

■ The white foamy surf we see in breaking waves is actually made up of lots of tiny droplets containing bubbles of air. These air bubbles do not absorb as much light as pure water droplets, so the light that has passed through them is brighter than the surrounding sea. This is what

usually gives surf its white appearance. This effect is more noticeable when seas are rough because the churning waves produce more aeration and therefore more bubbles. Pollution or dissolved organic matter in the sea (often produced by the decay of algal blooms) can also create white foam along the shore. **SF**

Only the breaking part of the wave appears white; the rest of the water remains transparent



Comet Lovejoy near the Earth's horizon, photographed from the ISS by NASA astronaut Dan Burbank



## What is the difference between an asteroid and a comet?

Nina Winslade

Asteroids and comets both orbit the Sun, and are the remains of objects formed in our Solar System. Sometimes their unusual orbits can bring them close to planets and moons. The difference is in their composition. Asteroids typically comprise rocks and metals, while comets have ice, dust and organic matter in addition to the rocky material. Asteroids stay stable and solid, but if a comet gets close to the Sun, some of its ice melts off. That's what gives comets their characteristic "tails" – fuzzy

trails pointing away from the Sun that contain ice and compounds such as ammonia.

Asteroids probably formed closer to the Sun, while comets formed further away in the Solar System and were able to retain ice. Some astronomers theorise that comets could have formed closer to the Sun and been flung out by gravitational forces from gas giants like Jupiter. Another difference between comets and asteroids is that the former can have huge, elliptical orbits, while asteroids usually have circular, shorter orbits. SF

## FASCINATING FACTS

### Trees live forever – sort of

Many plants grow from seed and then die back in a single year. But trees and shrubs don't have a fixed life span. One bristlecone pine in Nevada, USA, is over 5,000 years old. Unbe-leaf-able.



Quaking aspen trees have a single connected root system, making the colony effectively immortal

## How do monorails work?

Patrick Li

Most monorail trains just use wheels running over a single guide rail, with horizontal wheels clamping it to the rail on either side, so the train doesn't fall off. But some use maglev technology to float above the track. There are two main types: electromagnetic suspension (EMS) and electrodynamic suspension (EDS). EMS uses C-shaped arms that wrap underneath the track; electromagnets pull the train up by attracting the arms to the bottom of the track. EDS uses the train's motion to induce magnetic eddy currents in the metal rail, which creates a cushion of magnetic repulsion. Maglev trains accelerate using magnetic coils built into the side of the track. These create an overlapping pattern of alternating north and south magnetic fields. Instead of a conventional engine, the train rapidly alternates the direction of its own magnetic coils to attract the front of the train to the next coil along the rail. LV



## Why can't we digest sweetcorn?

Marc Drury

Although unchewed sweetcorn appears to be able to pass through the digestive system completely unchanged, it has actually been partly digested. The inside of the corn kernel is made up mostly of starch, and is easily digestible, but the outside is made from tough plant fibre called cellulose. Humans lack the digestive enzymes required to break down cellulose, so if you don't chew your sweetcorn properly it will pass through your digestive system whole. Digestive enzymes are able to diffuse across the membrane, breaking down some of the starch inside and releasing sugar molecules into the gut, but from the outside it looks almost exactly the same. LM



The tough outer kernel of sweetcorn cannot be broken down in the gut



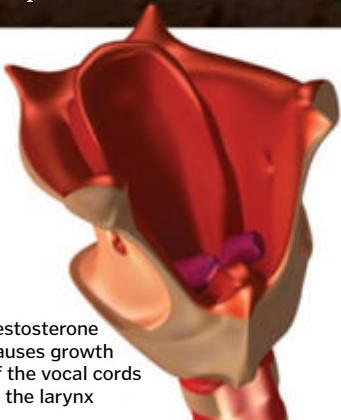
Slug pellets contain yeast as bait – it's irresistible to a hungry mollusc!

## Why are slugs attracted to beer?

Caroline Lewis

■ Slugs like yeast. In fact, they can smell the yeast in beer from about half a metre (1.6 feet) away, so you need to place beer traps no more than a metre (3.3 feet) apart. Beer traps aren't very effective, though. Studies with time-lapse cameras have shown that most slugs

manage to drink from a beer trap without falling in. The few that do topple in aren't affected by the alcohol; fortifying a slug trap with extra alcohol doesn't help and they work just as well using bakers' yeast and sugar. Slugs die in beer traps because they fall in and drown, not because they get drunk. LM



Testosterone causes growth of the vocal cords in the larynx

## Why do voices change during puberty?

Chloe Black

We speak by pushing air through two elastic vocal cords attached to cartilage in a structure known as the larynx, or voice box. The tissue in the voice box responds to the male sex hormone testosterone, so when levels rise during puberty it triggers thickening and growth. Just like the thicker strings on a guitar

make a lower sound when they vibrate, the thickening of the vocal cords can alter the pitch of a boy's voice by up to an octave.

The effect is accentuated by changes in the bone structure of the head, which allow the sound to resonate. Girls' voices also drop during puberty, but the change is much less noticeable. LM



It is purely a myth that spicy food burns off taste buds

## Can spicy food burn off your taste buds?

William Tucker

■ Although capsaicin – the spicy compound in chilli peppers – can temporarily numb the mouth to protect the body from the pain of the heat, it is a myth that spicy foods burn off our taste buds. The more we eat spicy foods, the more we are able to tolerate them, as we become desensitised to the heat. In addition to this, our sense of taste diminishes as we become older. Many mistake this gradual loss of a reaction as taste buds having been destroyed, but it is in fact a combination of getting used to spicy foods and taste bud cells dying over time. SB

## Does frowning increase the likelihood of wrinkles?

Darren Rogers

■ Facial expressions, including frowning and smiling, can all take their toll on the skin. The muscles that move your face compress the same areas of skin over and over again, forming lines that sit between the muscles. When we are young, our skin is oily and elastic, so it can easily spring back into place, but as we age the composition of the skin changes. We produce less and less of the structural protein collagen, which supports the skin cells, and the level of the elastic protein elastin gradually drops. The process is sped up by environmental factors like Sun exposure and smoking. LM



When we frown, our skin bunches up around our facial muscles



Infrared cameras convert invisible heat into a visible, measurable state

## How do infrared cameras work?

Gemma Rose

■ An infrared camera works by detecting infrared energy that we cannot see, and then converting this radiated heat, which can be felt on our skin, into an electronic signal. The signal is processed to produce a thermal image on a video monitor. An infrared camera therefore converts invisible infrared radiation into a visible state for us to see and then work out calculations to do with temperature. The main component of an infrared camera is the infrared detector. This is what converts the infrared energy into an electronic signal. Most detectors have two layers. There is electrical resistance between these layers, caused by heat striking individual pixels. Resistance values of individual pixels are converted by the device's electronics into thermal images and temperature values. SB

## New Brain Dump is here!

■ Don't miss issue 25 of Brain Dump, the digital sister magazine to How It Works, when it lands on the virtual newsstand on 1 June. You'll discover why children look like their parents, what exactly a hiccup is, as well as the answer to the question: if you freeze a can of soda, what happens to the bubbles? Each issue is packed with amazing images and loads more trivia snippets, giving you the knowledge hit you need without having to lug an encyclopaedia around! Download the new issue of Brain Dump on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask at [www.facebook.com/BraindumpMag](http://www.facebook.com/BraindumpMag) or Twitter – the handle is @BrainDumpMag.



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# REVIEWS

All the latest gear and gadgets

## Camping equipment

These camping accessories will make sure you're well equipped for every eventuality

With the summer weather well on its way, many of us will start embracing the great outdoors. Camping presents a number of challenges to us all, in particular leaving behind some of our beloved technology. Fortunately, many camping accessories enable you to stay in touch with the world, while also keeping you comfortable in all weather.

### Checklist

- ✓ Three-man tent
- ✓ Multi-fuel burner
- ✓ Solar-powered charger
- ✓ Sleeping mat
- ✓ Sleeping bag
- ✓ Water filter
- ✓ Steam charger



### 1 Inflatable frame

The Cave by Heimplanet

£549 (approx £405/\$614)

[www.heimplanet.com](http://www.heimplanet.com)

The Cave has an unusual design for a tent, which is actually based on the molecular structure of a diamond. It's very simple to erect, and can be completed in minutes using only one pump. It's expensive, but will definitely turn heads at any campsite or festival that you visit.

**Verdict:**

### 2 Outdoor cooking

Trangia Multi-Fuel Burner X2

£190 / \$229.99

[www.amazon.com](http://www.amazon.com)

Relying on a campfire to cook can be unreliable, which is why items such as the Trangia have become so popular. Working with a variety of gases including petrol and kerosene, this device is perfect for demanding winter tours and expeditions. It's very expensive, but is an investment worth making for serious camping fans.

**Verdict:**

### 3 Solar charger

Solarmonkey Adventurer

£85 / \$130

[www.powertraveller.com](http://www.powertraveller.com)

The Solarmonkey Adventurer is a strong, rugged device. It benefits from a nice, simple design, and as soon as you expose the two solar panels to sunlight, the red charging light turns on. It's heavier and larger than some of its competitors, but does provide three charging options including USB.

**Verdict:**

### 4 Water filter

LifeStraw

£22 / \$31

[www.cotswoldoutdoor.com](http://www.cotswoldoutdoor.com)

When you're camping in a remote location, accessing drinking water can be difficult. The LifeStraw is able to make microbiologically contaminated water safe to drink by filtering it using a hollow fibre membrane. Overall it works well and doesn't use chemicals, which is a nice feature. However, identifying a water source that is contaminated with something the LifeStraw can't filter, like dissolved chemicals, is an issue.

**Verdict:**

**Fuel pump**

Building sufficient pressure within the canister can be achieved in seconds, enabling you to light the burner quickly.

**Water resistant**

The Solarmonkey Adventurer is both water and shock resistant, making it sufficiently durable for outdoor use.

## 5 Lightweight and warm

**Nordisk Oscar +5°**  
£190 (approx \$260)  
[www.cotswoldoutdoor.com](http://www.cotswoldoutdoor.com)

This sleeping bag is exceptionally lightweight, and is designed to keep you comfortable in temperatures as extreme as -6 degrees Celsius (21.2 degrees Fahrenheit). It's very comfortable and even enables you to sit upright whilst in the sleeping bag. The colour won't be to everyone's taste though, and it doesn't offer great value for money.

**Verdict:**

## 6 Clean power and water

**BioLite KettleCharge**  
£160 / \$224  
[www.cotswoldoutdoor.com](http://www.cotswoldoutdoor.com)

The BioLite KettleCharge works to provide two key resources - clean water and power. It cleverly converts the heat generated from boiled water into electricity so you can charge a variety of devices via its USB. It even stores charge for you to use when you need it most. Although it is costly, you get two essential gadgets for the price of one.

**Verdict:**

## 7 Maximum comfort

**Sea To Summit Ultralight sleeping mat**  
£105 / \$147  
[www.cotswoldoutdoor.com](http://www.cotswoldoutdoor.com)

The Ultralight sleeping mat from Sea To Summit features a variety of technologies to keep you comfortable and warm. By reflecting body heat, the sleeping mat ensures that you remain warm even in the coldest of conditions. It also moulds to your body shape nicely when you lie on it. Inflating the mat isn't as rapid as you'd like, but can be done with minimal effort.

**Verdict:**

## EXTRAS

Get yourself in the know before you go



### Pitch Up, Eat Local

**Price:** £16.99 / \$27.95  
**Get it from:** [www.amazon.com](http://www.amazon.com)  
Written by The Camping and Caravanning Club, this book helps you get the most out of the area that you have chosen to camp in, by identifying the best local produce to eat. Each featured campsite is close to shops and markets where you can buy locally sourced ingredients, so you can really connect with the areas you visit.



### AccuWeather

**Price:** Free  
**Get it from:**  
[iTunes](#) and [Google Play](#)  
If you plan on spending a lot of time outdoors, an accurate weather report is a must. AccuWeather provides a range of forecasts, including a hyperlocalised report for the next two hours. It's free to download and could save you from getting caught in a downpour.



### Choosing a campsite

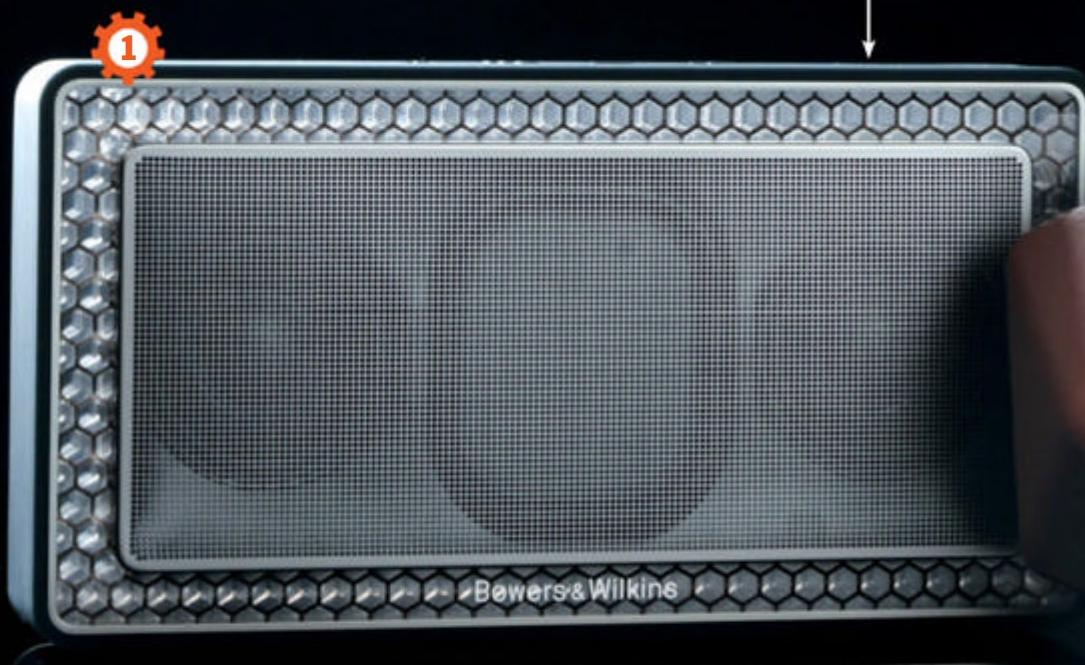
**Website:** [www.pitchup.com](http://www.pitchup.com)  
This website offers information on over 5,000 campsites in the UK and Ireland. It enables you to customise your search criteria, helping you find your ideal campsite. It's even possible to book pitches through the Pitch Up, simplifying the overall process of finding a campsite.

# GROUP TEST

Putting products through their paces

## Portable Bluetooth speakers

Blast out your favourite tunes even if you're on the go with these wireless wonders



**Lasting power**  
With 18 hours of playback, the T7's battery life provides plenty of listening time.

**Personal companion**  
You can choose from several voices for your Boom Boom via the app.



### 1 Bowers & Wilkins T7

**Price:** £299.99 / \$349.99

**Get it from:** [www.bowers-wilkins.co.uk](http://www.bowers-wilkins.co.uk)

The striking honeycomb effect surrounding the T7 not only makes the speaker look incredibly stylish and attractive, it also improves the sound too. The interlocking cells are designed to reduce vibration and distortion, and they do indeed help produce a rich, clear sound with plenty of detail. However, if you're planning on experiencing this superb sound while out and about then the heavy, bulky unit will add considerable weight to your bag.

Setting up the speaker is simple, but as the Bluetooth functionality is not activated automatically when you switch it on, you do need to press a button on the top each time you connect. Although this is frustrating, the resulting connection does deliver a pleasing jingle and a great range, as your music keeps playing even when your device is well out of sight.

If you have the money to spend, then this high performance speaker will make a stunning addition to your home, but with no other additional features to speak of, you may want to look elsewhere to get better value for money.

**Verdict:**

### 2 Binauric Boom Boom

**Price:** €199 / \$249 (approx £131)

**Get it from:** [www.binauric.com](http://www.binauric.com)

The simple, any-way-up design of the Boom Boom makes it look more like a piece of modern art than a speaker. As well as looking good in your home, it's also compact and lightweight enough to easily fit inside of your bag too.

When switched on, the speaker springs to life with a verbal greeting, a novelty that some will appreciate, but others may find a little unsettling and annoying. Nevertheless, this feedback is helpful when connecting it to your Bluetooth device, a process that is incredibly quick and easy.

The sound quality is disappointingly average and the Bluetooth connection has a habit of dropping out when it is out of line of sight, but the main selling points of the Boom Boom are its extra features and ability to evolve.

As well as playing music, the speaker can also be used to make phone calls and record sound, and over time you can add more functions via the companion app without having to splash out on new hardware.

**Verdict:**

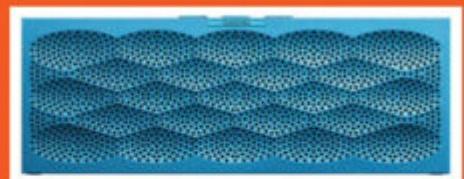
### MINI MARVELS

The pocket-sized speakers with mighty features



#### Bose SoundLink Mini

Although it weighs as much as the average tablet, the SoundLink Mini promises superior sound quality over your music-playing device.



#### Jawbone Mini Jambox

The sleek Mini Jambox is less than 25mm (1in) thick, but packs in a lot of useful features that can be regularly updated via an app.



### 3 Libratone Zipp

**Price:** £299.95 / \$399.95

**Get it from:** [www.libratone.com](http://www.libratone.com)

From the packaging to the speaker itself, the Libratone Zipp's design oozes class. The interchangeable wool covers are a great feature, enabling the speaker to be customised in a manner that many competing speakers can't be. The quality leather handle is also a plus, as it enhances the portability without compromising on looks.

Connecting your smartphone to the speaker is a simple task. It has a range of connectivity options, including Bluetooth and Wi-Fi. The Bluetooth connection is very reliable and means you don't need an internet connection to use the speaker. The ability to simultaneously charge your smartphone while streaming music is very clever, and it also works to combat the battery draining effect of Bluetooth that can occur on certain handsets.

The speaker's sound is also very impressive. It works superbly well over a range of volumes, providing excellent sound richness and thumping bass when required. The speaker really fills the room with sound thanks to the 360-degree sound projection design. Although the price may put some people off, the Zipp's design, sound quality and portability make it an investment worth making.

**Verdict:**

### 4 JBL Charge 2

**Price:** £129.99 / \$149.95

**Get it from:** [www.jbl.com](http://www.jbl.com)

The stylish Charge 2 offers true portability, as it will neatly slip into your bag and is durable enough to survive a few knocks and bumps on your journey.

The Bluetooth connection is quick and easy to set up and even holds up when the speaker and phone are in different rooms, but it does sometimes struggle to pair automatically on later attempts. Nevertheless, you and a few friends can all connect at once for shared control over the music, plus you can use the speaker to take calls thanks to the built-in microphone. If your phone starts running out of battery, you can also plug it in to charge. However, this does shorten the speaker's battery life considerably so it's a feature that is best left for emergencies, or if you just can't wait to upload that Instagram snap.

What's really impressive about the Charge 2 though is the excellent sound quality. For such a small and relatively cheap speaker, it delivers rich sound with plenty of bass and very little distortion.

**Verdict:**

### 5 Pure Jongo S3

**Price:** £129.99 / \$199

**Get it from:** [www.pure.com](http://www.pure.com)

As soon as you take the Jongo S3 out of its box, two things hit you. The first is the compact, uncluttered design that means it will look good in any room. The second is the weight; it feels very heavy for such a small speaker. Connecting to the speaker is pretty straightforward; we had no problems pairing a smartphone to it and didn't lose connectivity when streaming music. The small LCD screen at the back offers some limited information, but we found it quite frustrating to use as it's so small.

The sound quality is average and the bass is somewhat lacking, which is probably down to the tiny speakers. With up to ten hours of playback per charge, the Jongo S3's battery is very good; the battery can even be replaced when it wears out so you don't have to buy a completely new speaker. Although it doesn't offer the highest sound quality, the Jongo S3 is more affordable than some of its rivals.

**Verdict:**

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# Make pH paper

Learn how to make pH paper and test acidity in your own kitchen



### 1 Prepare your cabbage

First, the red cabbage needs to be prepared for cooking. Accompanied by an adult, chop the cabbage into small pieces and place them into a saucepan. Cover the chopped cabbage with water and then heat the pan until the water starts boiling. Turn the heat down and allow the cabbage to simmer for about 20 minutes, stirring occasionally.

**DON'T DO IT ALONE**  
IF YOU'RE UNDER 18,  
MAKE SURE YOU  
HAVE AN ADULT  
WITH YOU



### 2 Stain your paper towels

Once the cabbage has finished cooking, remove it from the heat and pour the saucepan's contents through a strainer, making sure the purple liquid is collected in a bowl. You will no longer need the cabbage itself so save it for a recipe. Once you are happy the liquid is cool enough to handle, add the paper towels and stir. Leave them to soak up the liquid for five minutes, until they've taken on the liquid's purple colour.



### 3 Dry and cut your paper towel

Take each paper towel out of the liquid and place onto a cooling rack to dry off. Make sure you put something underneath the cooling rack to catch the drips from the paper towels, as these can stain the surface below. Once the papers are dry, cut the paper towel into rectangular strips roughly 1.3cm (0.5in) wide. You are now ready to test the pH of different liquids.



### 4 Prepare your test liquids

It's now time to test out your pH strips! For this part you'll need test tubes, a stand and some household liquids. Good liquids to use are lemon juice, milk, vinegar and dish soap. Fill each test tube by half with a test liquid, then dip one test strip into each and leave for a few minutes. Keep watching the tubes to see the strips change colour.



### 5 Record your findings

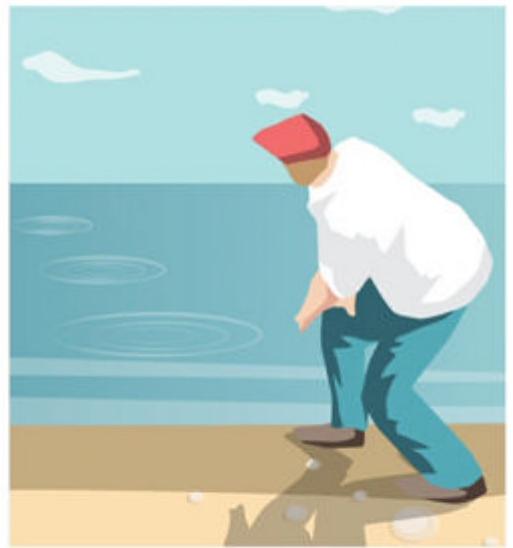
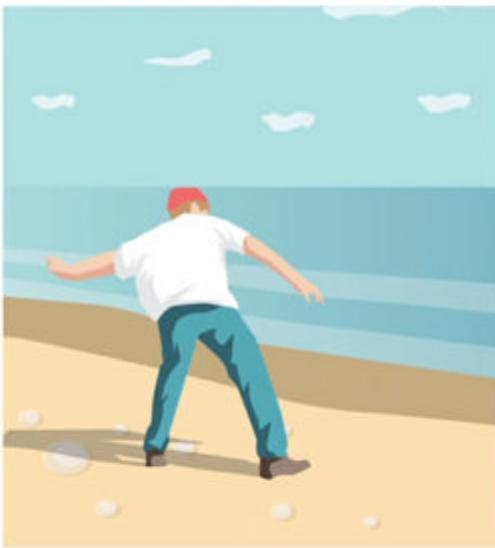
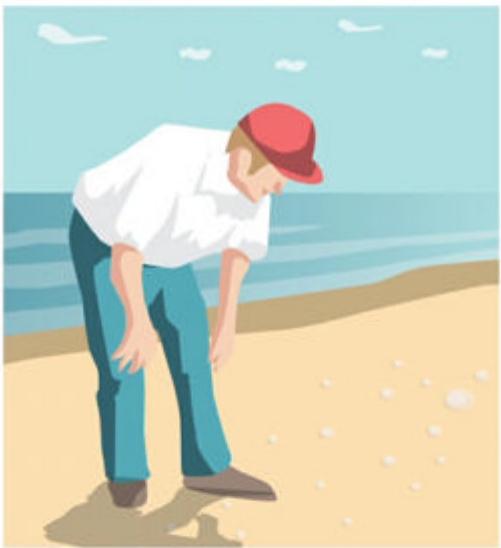
Once you're happy that the paper towel strips have spent sufficient time in the test liquids, you can remove them. If you can't do this with your fingers, use a wooden skewer. You should record the colour of each strip immediately; as once they begin to dry the colours will often lighten and become less clear. You could even stick them onto your worksheet to keep.

**NEXT ISSUE**  
- Make a model lung  
- Conduct a chromatography test

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# Skim a stone

Perfect your stone-skimming skills with physics



## 1 Select the perfect stone

The stone you choose to skim is vital. For best performance, it should be flat and even, fitting comfortably in your hand. The stone needs to be heavy enough to not blow away in a breeze, but if it's too heavy it will sink too fast. The ideal texture is debatable. A smooth stone seems an obvious choice, but a pitted stone may help to reduce water drag, similar to how pitted golf balls exhibit less air drag.

### In summary...

Skimming stones is a fun activity for the whole family, and would be great to try out in the coming summer months. Make sure you pick a calm day, as flatter water will help you achieve the best results. The current world record for the number of skips is 88, which was set in 2013 by Kurt Steiner. That's definitely something to aim for!

## 2 Prepare to throw

Hold the stone between the thumb and tip of your middle finger, with your index finger resting on top. Stand side-on to the water's edge. The optimum angle is about 20 degrees. As the stone touches the water, it pushes down. The water in turn will push the stone upward, propelling it out of the water. The stone has to be travelling at a certain speed, or it will momentarily 'surf' the water and then sink.

## 3 Set your personal best

Don't forget to flick your wrist as you release the stone, which will impart spin. Spinning the stone is crucial in getting a high number of skips. This is due to the gyroscopic effect, which ensures the stone remains stable as it travels along the surface. For this to occur the stone must spin with a certain minimum rotational velocity; at least one complete rotation must be completed on each bounce.



# WIN!

An activity tracker wristband

The Fitbit Charge tracks your steps taken, distance travelled, calories burned and floors climbed. It can even monitor your sleep too and the Silent Alarm function will wake you with gentle vibration. Plus, Caller ID vibrates to alert you to incoming calls.

How many millions of years ago did the dinosaurs become extinct?

- a) 150 b) 66 c) 20

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## Why flies aren't faster than cars

■ Dear HIW,

My 11-year-old son Nino and myself love our new subscription of HIW! It has a great mix of interesting facts and new developments for all age groups. We're wondering if you could help us answer a question we recently thought of. If a fly is locked in a car, and flies from the back of the car into the front while the car is in motion, is it flying faster than the car? Thank you!

Lotta & Nino Rossler

## Letter of the Month

# Why do people's tastes differ?

■ Dear HIW,

I love reading your magazine each month! I read the section in issue 71 where you explain why we crave sweet things, which made me think, why do we have different preferences in food to one another? For example, some love Marmite but some hate it. If the reason we like and dislike things is because our ancestors needed high-energy foods, why do our taste preferences differ? Thanks,

Patrick Clare

The papillae on our tongues house our taste buds. People who have lots of papillae tend to find certain flavours too strong; they're more likely to order a mild curry rather than a vindaloo. You can find out whether or not you are a 'supertaster' with the help of blue food dye and a paper ring (like a hole-punch reinforcer). Simply apply some dye to the tip of your tongue using a cotton bud, and pop the paper reinforcer over the same area. Use a mirror or ask a friend to count the number of pink bumps they can see within the ringed area. If you've got more than about 30 to 35, this means you're a 'supertaster.' Our individual taste preferences aren't just about the number of papillae we have, though; our taste buds' ability to detect certain molecules is also involved. All of us recognise the same five tastes; what's interesting is that different chemicals, from person to person, trigger the signals for each taste. This is likely to be the real reason why our taste preferences differ, as certain foods will trigger particular tastes in one person, but not in another.

We have a natural aversion to bitterness, as most toxic plants exhibit this trait. This is why children often dislike rhubarb



A fly is able to do this because the air within the car is relatively stationary. This means the fly isn't travelling at a greater speed than the car, and is the same reason why someone who jumps in a plane isn't hurled into the back of the aircraft. If you quickly accelerate while the fly is in motion, it will actually be forced forward, due to air pressure building at the back of the vehicle.

## How to survive a desert island

■ Dear HIW,

I'd like to start by saying your magazine is amazing! My question is the following; could you survive a desert island if you only drank salt water?

Thanks,

**Titus Macdermot (aged 11)**

Unfortunately, you wouldn't survive for very long. The problem with

drinking salt water is that it causes dehydration; after drinking it you'll need fresh water to flush most of the salt out of your body. This is a commodity you're unlikely to have on a desert island; the best option is to treat the salt water to make it a more appropriate source of hydration. The process of solar desalination uses sunlight's heat to remove salt, producing fresh-water condensation. With this fresh water, it's possible to survive for ten days or longer.

Sea water is much saltier than the fluids in our body, so drinking it will actually dehydrate you





People who lie awake while their partners snore are thought to lose one hour of sleep per night on average

## "The problem with drinking salt water is that it causes dehydration"

### Why men snore more than women

■ Dear HIW,  
I have a question for you. Why do men snore more than women? I have really enjoyed your magazine since I became a subscriber last Christmas.  
Many thanks,  
**Joakim (aged 10)**

Hi Joakim, thanks for your letter. It's true that twice as many men snore than women. Although snoring can

be caused by nasal obstruction or enlarged adenoid tissue, there is a biological reason why men are more commonly the culprits. This is down to the way we have evolved to speak. As we developed speech, our voice boxes were forced to drop lower in our necks, which created a space behind our tongues. This space, called the oropharynx, is larger in men. This means that when the tongue falls back into the space, it is more likely to wake women up, whereas men can continue to breathe, so they stay asleep and keep snoring.

A screenshot of the How It Works website homepage. The page features a navigation bar at the top with links like 'HOME', 'ABOUT', 'CONTACT', 'ADVERTISE', 'SUBSCRIBE', and 'LOG IN'. Below the navigation is a large banner with the text 'Your daily dose of knowledge'. Underneath the banner, there are several article thumbnails with titles such as 'How to make a black hole', 'How to make a rainbow', and 'How to make a comet'. To the right of the banner, there is a section titled 'Wall of knowledge' with a list of bullet points: 'Wall of knowledge', 'Interviews', 'Q&amp;A', 'News', 'Competitions', 'Fully annotated illustrations', 'Videos', 'Top fives', and 'Competitions'. At the bottom of the page, the website URL 'www.howitworksdaily.com' is prominently displayed in a large orange font.

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I love the How It Works factoids!

@SoozHodges

@HowItWorksmag my favourite Great Day Out - The Observatory Science Centre

@amyhj23

@HowItWorksmag FACT! The entire internet weighs about the same as one large strawberry.

@neiltysen

Meteors meet fiery deaths as they plunge through Earth's atmosphere. So the term "Meteoric Rise" makes no sense whatsoever.

@NikiMarieWardle

@HowItWorksmag I have odd feet (4 1/2 & 6) does that mean my arms should be odd too...?

@RichardDawkins

Whistling requires precise tongue positioning, like a finger on violin string. Yet most can whistle tunes without training. Interesting?

@ProfBrainCox

New Horizons at Pluto – really excited about this.

@StationCDRKelly

Earth's gone #green today! Good morning from @space\_station where every day is #EarthDay! #YearInSpace

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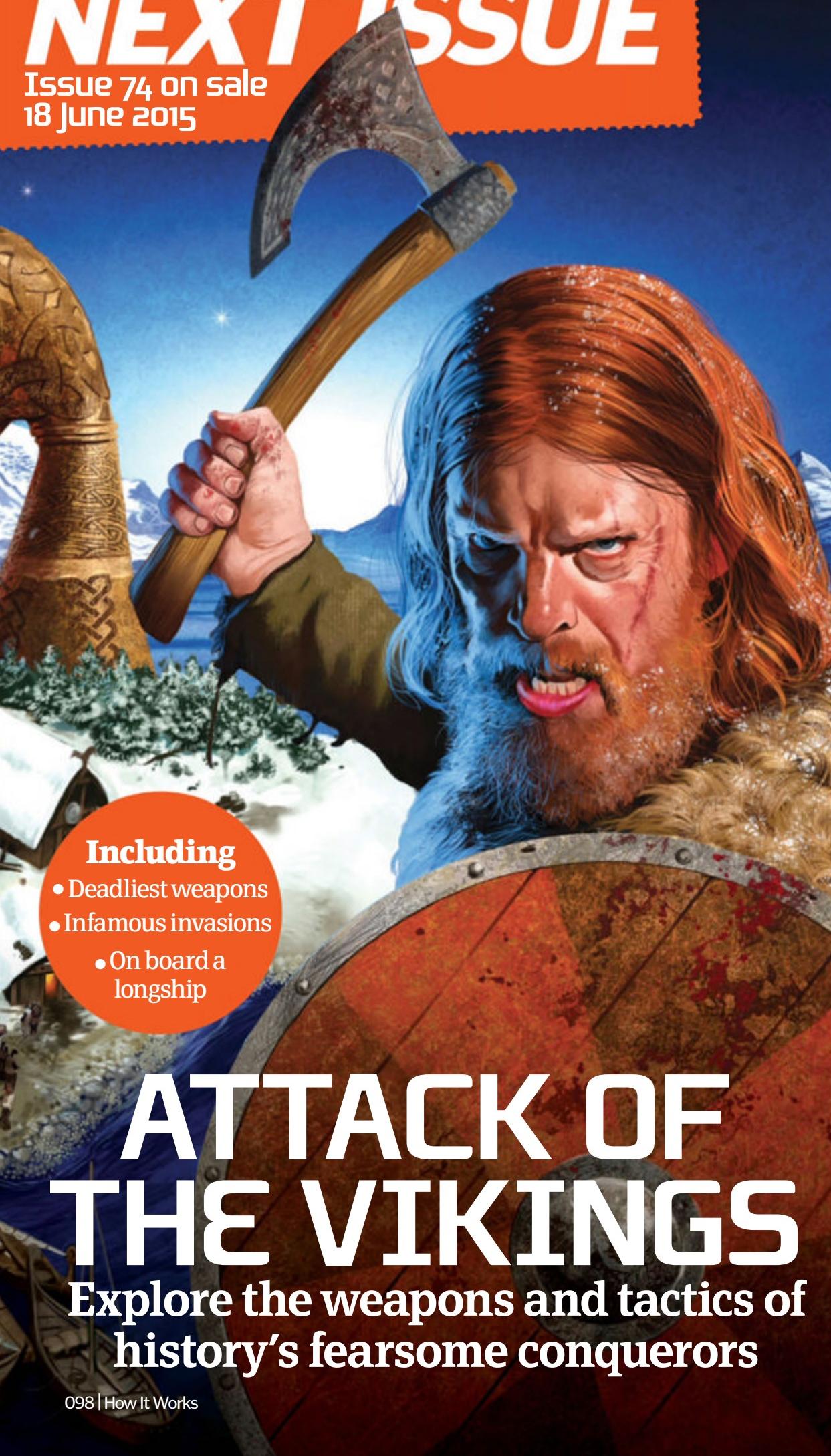
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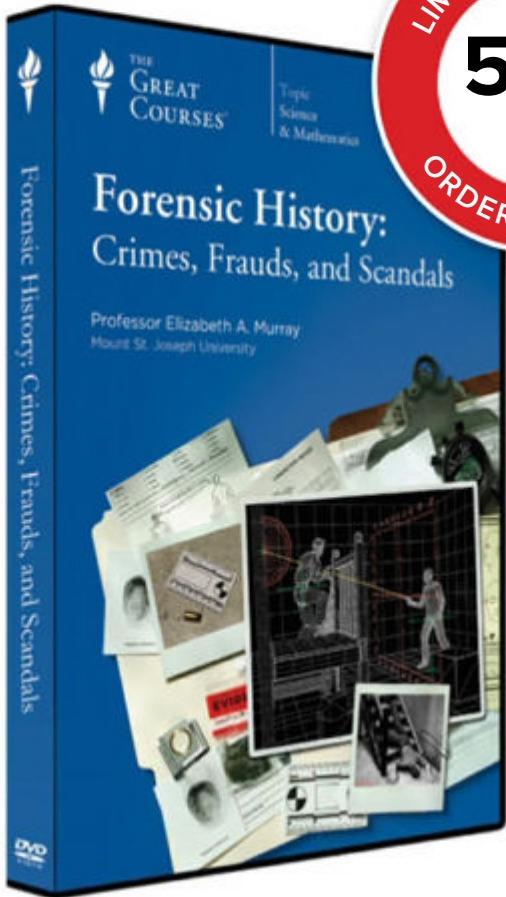
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